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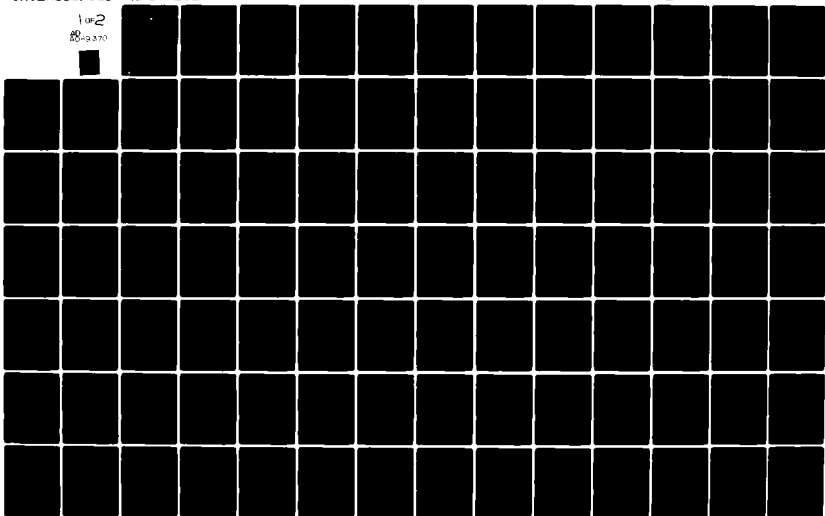
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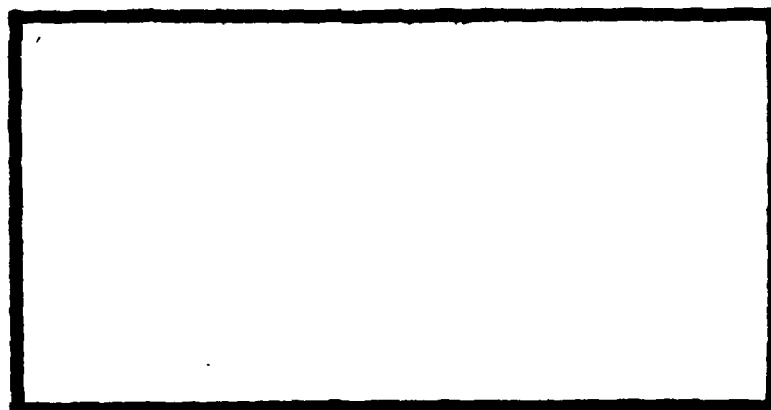
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9 Master's thesis

6 A DYNAMIC MODEL OF THE AIR FORCE
GRADUATE EDUCATION SYSTEM.

10 John R. Baker Squadron Leader
Mr. Stephen C. Forgie

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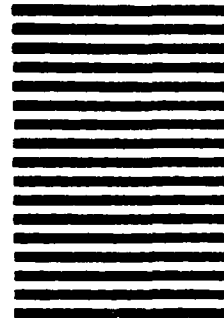
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5 The Air Force's Advanced Academic Degree Management System (AADMS) consists of a number of unrelated and dynamically changing parts which provide a challenge to AADMS managers' ability to create and operate an effective decision structure. A computerized model which caters for features both internal to, and external to, but impacting upon the system, has been designed to allow managerial experimentation with policy decisions. As well as potential policy decision implications, the model enables an analysis of system response to factors not directly under the control of the Air Force.

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A DYNAMIC MODEL OF THE AIR FORCE
GRADUATE EDUCATION SYSTEM

A Thesis

Presented to the Faculty of the School of Systems and Logistics
of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the
Degree of Master of Science in Logistics Management

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has been accepted by the undersigned on behalf of the faculty
of the School of Systems and Logistics in partial fulfillment
of the requirements for the degree of

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COMMITTEE CHAIRMAN

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Chapter 1

INTRODUCTION

BACKGROUND

Department of Defense (DOD) Directive 1322.10, Policies on Graduate Education for Military Officers, establishes DOD policies on graduate education requirements for military officer positions and the utilization of qualified military officers in those positions (26). Graduate education is education directed towards an advanced academic degree (AAD), i.e., a masters degree or doctorate.

The program is intended to benefit the Department and the individual officer by: (1) insuring higher levels of professionalism and technical competence within the DOD; (2) recognizing the educational aspirations of individuals; and (3) providing incentives for recruitment and retention of personnel with ability, dedication and capacity for growth [26:1].

At the Air Force level, procedures for determining advanced (graduate level) degree requirements, and for utilizing the holders of advanced degrees, are contained in AFM 36-19, Advanced Academic Degree Management System (22). The stated primary objective of the Advanced Academic Degree Management System (AADMS) is "to ensure that academically qualified officers are available, at all times, to solve Air Force managerial and technological problems [22:1-1]."

Research has shown that, prior to the FY 1971 budget hearings, Congress had shown little interest in the graduate education programs of the Services (10:7). In 1970, the Services' graduate education programs came under the scrutiny of the General Accounting Office (GAO). In a report to the Congress, the GAO sharply criticized the Services' procedures for identifying and approving positions (billets) requiring graduate level incumbents and for managing the utilization of those officers who had received graduate education (29:1,2). Thus began a period in which the Services' graduate education programs were subjected to increasing Congressional scrutiny and criticism, resulting in Congressional cuts in DOD budget requests for fully-funded graduate education in FY 1974, FY 1979 and FY 1980. (Fully-funded graduate education involves full-time study which is entirely paid for by the Service). In reviewing the FY 1979 DOD request for graduate education funding, the House Appropriations Committee stated:

It is the belief of this Committee that the Department of Defense has disregarded the guidance which has been provided by the Committee on improving the management of professional development and education within the Department of Defense, and that a considerable degree of inefficiency and lack of management control pervades the program [19:29].

In assessing the FY 1980 request for graduate education funding, the House Appropriations Committee recommended that a request for small increases (over FY 1979 levels) in the numbers of Navy and the Air Force Officers (89 and 40

respectively) to undergo graduate education be disallowed and the input levels be held to those approved for FY 1978. The Committee also stated that any increases sought for FY 1981 must be accompanied by "demonstrable improvements in program management [20:63]."

Management Problems Perceived
by Congress

The following aspects of the DOD graduate education program are perceived by Congress as management problems.

1. The procedures for determining the requirements for graduate education are too subjective (19:28).

2. The inventories of officers already possessing graduate degrees is not being efficiently utilized (18:25).

3. The two DOD graduate schools - the Naval Postgraduate School (NPG) and the Air Force Institute of Technology (AFIT) are not being efficiently utilized, that is, Service students are being sent to civilian institutions to undergo courses already available at the DOD graduate schools (20:63).

Management Problems Perceived
by the Air Force

While there can be little doubt that Air Force education managers in general would prefer that Congress had not become so deeply involved in graduate education, a result of Congress' stand has been that the Air Force has sought to identify significant shortcomings in the AADMS. A list of

shortcomings, perceived to exist in the AADMS by educational managers assigned to the Air Staff and the Air Training Command (ATC), was included in a letter to all Air Force major commands from the Director of Personnel Programs, HQ USAF dated 20 March 1979. The shortcomings listed were:

Though highly quantitative in operation, it is based on the subjective judgments of unit supervisors who have comparatively narrow views of the educational requirements of larger units and total career fields

Perceived to be complex and unwieldy, requiring supervisors to possess or obtain detailed knowledge of educational programs and codes and to process forms through a layer of reviews

Unresponsive to changing requirements because of the time involved in documenting, screening, approving, and programming newly identified needs

No means of distinguishing between the total inventory of AAD holders and real, usable assets

All degrees in a given field appear equal regardless of quality, areas of special concentration, obsolescence, etc.

General value and transferability of advanced education subordinated to a narrow concept of "utilization", i.e., assignment to a validated billet

No effective procedures for forecasting long-range educational requirements

Viewed by Congress as being based on too much subjective judgment and as encouraging the identification of billets to enhance the prestige of position incumbents [25:2].

Contact with HQ USAF Manpower Personnel Programs (MPP) staff confirmed that the above list accurately reflects the current concerns of HQ USAF/MPP with regard to the AADMS (5).

There is evidence that the Congressional cuts in funds for fully-funded Air Force graduate education is viewed with considerable concern within the DOD and the Air Force, particularly with regard to scientists and engineers. In addressing the December 1978 graduating class of AFIT, Deputy Secretary of Defense, Charles W. Duncan, Jr., stated:

At the same time that the need for advanced technical and scientific education is increasing, congressional austerity and other demands have reduced the number of man years annually invested in graduate education for line officers. In 1973 it was 1,820. In 1979 it's 955. A shrinkage of almost 50 percent. . . . As a defense problem, we've got cause for concern [7:33].

In presenting the proposed FY 1980 Air Force Education and Training Program to the Subcommittee on Manpower and Personnel, Senate Armed Services Committee, Major General Charles G. Cleveland, Vice Commander of Air Training Command, stated that the proposed fully-funded graduate education programs reflected congressional wishes for reduced inputs but was "not sufficient to meet the educational requirements of the Air Force on a sustained basis [4]."

In summary, Congress is dissatisfied with several aspects of DOD's current procedures for managing graduate education programs and has indicated its intentions to hold the numbers of inputs to fully-funded programs, for each of the Services, to FY 1978 levels. As of December 1978 the Air Force was experiencing shortfalls in usable assets of AAD holders of about 1300 (7:33). Accordingly, Congress' actions have led to an attempt by the Air Force to delineate

the shortcomings of the current AADMS and to a perceived need for a full review of the conceptual basis, and management, of fully-funded graduate education programs (25:1).

In the decade since the GAO reported deficiencies in the DOD graduate education programs to Congress in 1970, various attempts have been made by DOD and the Services to improve the cost-effectiveness, overall management and acceptability (to Congress) of the programs. That the changes made thus far have not been entirely successful is evidenced by the continuing concerns of Congress and the Air Force. At this stage it appears that major revision of the current system, or development of a new system, is required. At the least, some revisions of policies and procedures will need to be carried out.

In a 1975 review of the overall military officer education processes, Rose and Dougherty stated:

Neither the Office of the Secretary of Defense nor the Services consider, manage or fund the various educational or developmental program elements in a "system" context to a feasible or desirable degree; yet, they do in fact comprise a system [15:1].

Without, at this stage, defining the boundaries of the system precisely, the complexity of the system is evidenced by the number of separate elements involved in determining requirements for validated billets, determining annual quotas of students, selecting and assigning personnel to undergo graduate education, and utilizing graduate level resources. Many decision makers, at various levels, and in functionally

distinct areas, are involved. According to Shannon, such complex systems often exhibit counterintuitive behavior when efforts are made to secure improvements:

Cursory examination of complex systems will sometimes indicate needed corrective action, which is often ineffective or even adverse in its results. Cause and effect are often not closely related, in time or space; symptoms may appear long after primary causes. Obvious solutions may actually intensify a problem, rather than solve it [16:37].

Thus, Air Force managers have a need for information on how the current system actually behaves, and how proposed policy changes are likely to affect behaviors of the system. This information is needed to facilitate the development of new policies which will be effective in enabling the system to meet its objectives.

The need for such information with regard to complex systems in general has led to the extensive use of simulation techniques, in which a model of the system is developed and used to describe the behavior of the systems, and to predict the effects of changes to the system (16:2). "The value of a model arises from its improving our understanding of obscure behavior characteristics more effectively than can be done by observing the real system [8:49]."

PROBLEM STATEMENT

The Air Force needs to gain a better understanding of how the graduate education system actually behaves, and to be able to predict the effects of policy changes on the system prior to their implementation.

RESEARCH QUESTION

Can the behavior of the current Air Force graduate education system be determined and documented in a manner that will be useful to Air Force managers in understanding the behavior of the system, and in evaluating the effects on the system of changes in system policies?

RESEARCH OBJECTIVES

The general objective of this research was to develop an understanding of the behavior of the Air Force system for managing graduate education and to reflect this understanding in the form of a computerized model. The specific objectives emanating from the general objective were:

1. Identify the structure of the Air Force graduate education system.
2. Identify the interrelationships between the components of the system.
3. Describe the flow patterns which exist between the components of the system.
4. Construct a mathematical model which represents the components, interrelationships, and flow patterns of the system.
5. Portray this logic in a computerized model.
6. Validate the model to demonstrate that it adequately replicates the Air Force graduate education system structure and decision making process.
7. Identify areas of sensitivity of critical areas in Air Force graduate education management policy.

Presentation of Research

The presentation of the subsequent chapters generally follows the sequence of the research objectives. Chapter 2 presents a literature review to provide a historical background, and shows current operational processes within the AAD system. Chapter 2 also presents the rationale for applying a systems analysis approach towards problem solving.

The system dynamics methodology applied in this research of the AAD system is outlined in Chapter 3. Chapter 4 describes the information flows and decision processes of the system and constitutes the initial formulation of the model. Development of the mathematical model follows in Chapter 5.

A discussion of sensitivity analysis of the model is contained in Chapter 6 and is followed by a summary, conclusions, and recommendations in Chapter 7.

Chapter 2

LITERATURE REVIEW

Introduction

The nature of the research effort led to a review of literature pertinent to two distinct areas: (1) evolution of and past research into, the Air Force system for managing graduate education; and (2) available approaches or tools for addressing the problem. Terminology peculiar to the Air Force is presented in Appendix A.

THE AIR FORCE GRADUATE EDUCATION SYSTEM

Air Force Graduate Education - A Perspective

The Air Force has several programs designed to ensure that its officer corps receives the education and training¹ necessary to meet perceived needs. These programs

¹For the purposes of this proposal, "training" refers to instruction in military subjects either at a basic level, as in recruit training, or in a military or job-related technical specialty, such as pilot training. "Education" refers to study either in more advanced subjects or in military subjects which apply to an entire Service or to the broad mission of national security (Military Manpower Training Report FY 79).

may be divided into those which are designed to ensure accession of suitably educated and trained officers, and those which are aimed at providing post-commissioning education and training.

The precommissioning programs include the Air Force Academy, the Air Force Reserve Officer Training Corps (AFROTC) and the Airman Education and Commissioning Program (AECF).

Major post-commissioning programs include Specialized Skill Training, which provides officers with new or higher levels of skill in military specialties to match specific job requirements; Flight Training, primarily comprised of undergraduate pilot and navigator training; and Professional Development Education (PDE).

Whereas Specialized Skill Training is directed toward specific job skills, Professional Development Education is concerned with broader professional development goals in such subjects as military science, engineering, medicine, and management [28: VII-1].

The term "Professional Development Education" includes Professional Military Education (PME) and Advanced Academic Education. The former term covers education provided at the junior, intermediate and senior Service schools and colleges, which is designed to provide for "the development of military officers who are fully qualified to perform duties of high responsibility in both war and peace [28:VII-3]." The Air Force and Joint Service schools/colleges involved are the Squadron Officer School (junior level), Command and General

Staff College and the Armed Forces Staff College (intermediate level), and the Air War College, the National War College and the Industrial College of the Armed Forces (senior level). Within the Air Force, therefore, graduate education is only one of several programs of training and education, the overall purpose of which is

. . . to give the individual Service member the skills and knowledge that will qualify him or her to perform efficiently in subsequent assignments as a member of an operational military organization [28:I-1].

Historical Background

From the inception of the Air Force as a separate service in 1947 until 1959, various attempts were made to develop guidelines for the management of graduate education. In 1959, the first Education Requirements Board was established at Headquarters Air University (18:11). The Board included representation from the Air Force Academy, HQ USAF and the major air commands, and had the task of determining advanced degree requirements in terms of percentages for each Air Force Specialty Code by level of degree and academic specialty. The determination of requirements was performed by panels of officers. The Education Requirements Board was disbanded in 1965 (18:12).

With the discontinuance of the Education Requirements Board in 1965, responsibility for determining advanced degree requirements was assumed by HQ USAF (Director of Personnel Planning). Requirements were based on the annual position survey of all officer manning document positions by the major commands (10:127). The initial survey for FY 1965 resulted in a total requirement for 11,350 advanced degrees. Strict instructions from HQ USAF to report only those requirements considered essential resulted in a total requirement for FY 1966 of 7,763 advanced degrees (18:12).

In 1967, the annual survey was replaced by a review of positions, by career area, on a two year cycle (17:12-15). The reviews were carried out by the major commands and the consolidated results were forwarded to HQ USAF for validation by the Director of Personnel Planning (18:15).

In 1968, the Air Force reestablished the Education Requirements Board, called the Air Force Education Requirements Board (AFERB). The board was chaired by the Director of Personnel Planning with at least eight other members appointed by the Chief of Staff. As with the previous Education Requirements Board, panels of specialists for each career area were used to determine requirements. Based on the two yearly position reviews of their career area, the panels were responsible for validating current requirements and for making a five-year projection of advanced degree needs. The AFERB would then review the findings of each

panel (18:15-16). In 1970, the highly critical GAO report was published (29) and in 1971 DOD Directive 1322.10, Policies on Graduate Education for Military Officers was issued to alleviate GAO criticisms (10:127). In FY 1971 and 1972, a position-by-position survey of AAD requirements for Air Force line officers in all career areas was conducted. The results of the survey were vetted by the major commands and HQ USAF functional managers before presentation to the AFERB. The AAD requirements approved by the AFERB were returned to the major commands for entry into the manpower data system, effective July 1972. The establishment of a base AAD requirements level provided a basis for the current management system.

The Current Air Force Advanced Education System

The current advanced education system is based on the Advanced Academic Degree Management System (AADMS) which was instituted with the issuance of AFM 36-19 on 14 November 1972. The primary objective of the AADMS is "to ensure that academically qualified officers are available, at all times, to solve Air Force managerial and technological problems [22:1-1]." The AADMS also has career management objectives:

- (1) To provide an officer with a visible goal to pursue in developing his academic qualifications to fulfill an Air Force requirement.
- (2) To identify career progression opportunities and provide incentives for an Air Force career officer possessing or pursuing an AAD [22:1-1].

and personnel management objectives:

- (1) To provide functional managers and assignment officers with the necessary information to optimally use advanced degree resources, within the constraints of total mission accomplishment.
- (2) To provide guidance to Air Force Institute of Technology (AFIT), personnel programmers, selection personnel, and counselors for establishing the programs and selecting the officer inputs to satisfy validated advanced academic degree requirements.
- (3) To forecast advanced degree requirements caused by technological change that could result in the development of new academic disciplines or the increased emphasis on current disciplines [22:1-2].

The policies and procedures detailed in AFM 36-19 apply to all Air Force active duty line officer positions, except Judge Advocate General (JAG), in the grade of colonel and below.

Identification, Reporting and Validation of AAD Requirements

The process of identifying positions requiring AAD qualified incumbents begins with the supervisors of officer positions. Semiannually, each supervisor is required to survey all authorized line officer positions (except JAG), in the grade of colonel and below, which are under his immediate control to assess whether AAD requirements need to be adjusted. While guidance for supervisors is provided in AFM 36-19 (22:1-2, 4-3), the determination of AAD requirements by the supervisor is a subjective judgment. Results of the survey are forwarded through normal channels on Air Force Form 1779, Request to Establish/Change Advanced Academic Degree Position, to the appropriate functional

managers for each career area at the major command headquarters. AF Form 1779 includes the designation of the desired degree level, major academic field (in four-digit Academic Specialty Code), description of the duties of the position, and justification for the AAD.

The major command functional manager reviews and consolidates requests for new or changed AAD requirements within his career area and forwards requests which he considers to be valid to HQ USAF. The major command functional manager has the authority (and the responsibility) to disapprove and return to the originator requests which he believes are not justified. Major command functional managers are also required to notify HQ USAF of likely future changes in AAD requirements that he forecasts as necessary due to, for example, a technological change in his functional area.

The HQ USAF functional manager, and a career area panel of officers appointed by the functional manager, review, validate and approve or disapprove new requirements or changes to existing AAD requirements submitted by HQ USAF agencies, major commands or separate operating agencies (SOAs). Each career area has a ceiling on the number of AAD requirements which can be approved. Ceilings are set by the Air Force Education Requirements Board (AFERB). Although, in unusual circumstances, the functional manager can request the AFERB to raise the ceiling, he is generally required to meet any additional AAD requirements from within the current ceiling.

Requirements approved at HQ USAF are returned to the appropriate major command or SOA functional manager who forwards the requirements to the command manpower and organization staff for entry into the manpower data system.

The Air Force Education
Requirements Board (AFERB)

In accordance with AFM 36-19, the mission of the AFERB is to approve "current and future line officer AAD position requirements to accomplish the Air Force mission [22:2-3]." The board is chaired by the Director of Personnel Programs and has at least nine additional members. The AFERB is required to meet at least every two years to conduct a review of all AAD requirements. The AFERB is also responsible for development of the Air Force position on current and future qualitative and quantitative AAD requirements, acting on the advice of HQ USAF functional managers.

Determining Graduate Education
Quotas

Graduate education quotas are determined by comparing the inventory of AAD holders with a resource objective. The objective is obtained by multiplying the number of validated billets by a manning factor of 1.6. The manning factor is intended to allow for the non-availability of some AAD holders to serve in validated billets. On a quarterly basis, HQ USAF personnel staff use a computer program to compare

the validated billets, by Academic Specialty Code (ASC) and grade, with the resource objective over a five-year "window". The program includes forecasts of losses from and additions to the inventory of AAD holders, using historical data. Within budget and manpower availability constraints, the projected five-year shortages are converted into three annual quotas, with each quota being set to satisfy about one third of the total shortages.

Selection of Officers to Meet Quotas

The Air Force Manpower and Personnel Center (MPC) is responsible for the selection of qualified officers to undergo fully-funded graduate education to meet quotas. A list of officers qualified to undertake the needed graduate education is developed by AFIT (using the AFIT academic records of all active duty Air Force officers) and is forwarded to the MPC, where selections are made by panels of resource managers and career development monitors. Once selection is made, AFIT selects the school and completes the entry requirements. Approximately 46 percent of Air Force fully-funded graduate education is conducted at civilian institutions with the remainder being conducted in residence at AFIT (28:III-1).

Management of the Inventory of AAD Holders

The MPC is responsible for ensuring that graduates of fully-funded programs are assigned to a validated

position as soon as practicable after graduation. The MPC is also responsible for ensuring that graduates of fully-funded programs are assigned to validated positions in as many subsequent tours as requirements and career development objectives permit.

Other Sources of AADs

The fully-funded full time graduate education program is not the only source of AAD holders. In fact, the majority of officers within DOD who possess AADs obtained them through other than fully-funded programs (28:II-8). Within the Air Force, other sources of AAD holders include the Minuteman Education Program (MMEP), the Educational Delay Program, Tuition Assistance Programs and Veterans Administration (VA) assistance. Although details of graduate degrees obtained from outside the fully-funded program are entered on the officer's records, and such AAD holders are included in the current inventory of AAD holders, there are reasons why utilization of these officers in validated billets is limited. The Air Force usually has little or no control over the field of study and therefore the content of the course may not meet Air Force needs, the degrees may be in disciplines having few validated billets (or an existing surplus of AAD holders), and the degree holders may be too senior for the available billets (28:II-9).

A Segregated or Integrated Approach

There have been various investigations and changes to the graduate education system and these have been outlined in the previous sections of this literature review. Research efforts such as that undertaken by Hale and Rooney (9) investigated the benefits to the Air Force of providing officers with Advanced Academic Degrees. Sherwood's research indicated that AAD holders possessed greater promotion potential than non AAD holders (17). Thorne's research in 1970 addressed two critical problem areas existing for the Air Force in the AAD field at that time. The two areas were; problems in establishing correct Academic Specialty Codes and incorrectly utilizing AAD holders either because of poor specialty code matching or inappropriate AAD billet allocation (17). Other research in the early seventies centered on singular specific problem areas within the broad spectrum of the Graduate Education system.

Probably the most significant research effort in attempting to synthesize all the problem areas and view the total system was carried out by Rose and Dougherty (15:11). They advocated the use of a systems model which should take cognizance of a multitude of factors directed towards increased future requirements and should also address alternate methods available within the educational system to meet those requirements. Rose and Dougherty advocated the inclusion of such factors as personnel costs, quality of life

and alternate forms of AAD education (15:21-22). The authors' main thrust was to advocate a continuum of education rather than an ad hoc tiered system. Rose and Dougherty stated that bold new initiatives would be required on the part of Service planners and managers to meet the challenge of future unprecedented needs and reduced resources (15:22).

To assist managers in meeting this challenge, the system dynamics model enables first, a clear and demonstrable display of the relevant system structure to better aid understanding, and secondly, alternate decisions (i.e., the efficient determination and matching of needs and resources) to be tested for their respective impacts on the system model before implementation.

SYSTEMS APPROACH

Systems Problem Solving

In selecting a suitable problem solving technique it is desirable to examine not only the nature of the problems but also the context in which the problems exist within the system. It is necessary to clarify what is meant by a system and more particularly a dynamic system. In this context a dynamic system shall be defined as an orderly, interconnected complex arrangement of specified components set in the fluidity of time (12:1124). In taking this systems approach, any deviation from the desired output norm of the system is evidence to suggest that a problem exists within

the system. To effectively correct the deviation it is necessary to locate the problem and then rectify it. The preceding statement appears very simplistic and obvious, however, in a complex system consisting of many interacting parts, cause and effect relationships cannot always be uniquely and clearly identified. Consequently the real cause of a problem may be quite obscure and considerable effort may be wastefully directed in rectifying the apparent problem while the real problem remains unsolved. Moreover, even if the real problem can be located, the subsequent rectification may have unintended consequences throughout other parts of the system. Many problems develop over time and frequently other parts of the system will attempt to provide their own corrective or compensating actions.

Because of the aforementioned interactions and complexities of our environment there is now substantial support for the systems approach to problem solving. In the words of Ackoff:

The systems approach to problems focuses on systems taken as a whole, not on their parts taken separately. Such an approach is concerned with total-system performance even when a change in only one or a few of its parts is contemplated because there are some properties of systems that can only be treated from a holistic point of view. These properties derive from the relationships between parts of systems: how the parts interact and fit together [1:27].

Beer takes this approach one step further by stating that it behooves us to invoke the use of science (in its widest

sense) as the means of designing (and examining) complex systems through general systems theory (2:381).

The preceding background review was essential not only in identifying perceived problems and areas of concern, but also in identifying in general terms the various components of the system such as the Congress, DOD, HQ USAF, users of AAD holders and educators. The components have been broken down and added to for a more detailed analysis in the methodology.

Identification of the components alone does not assist in understanding the various interactions between them. It is important to develop a knowledge of how the system components are linked so that material and information flows may be identified. This identification of flows is necessary prior to the application of controls through policy decisions.

Modeling of Systems

Since it can be impractical in complex dynamic systems, for reasons of cost and possible undesirable consequences, to apply experimental problem solving decisions to real world situations, a model is an ideal vehicle for use as a testing ground. A model may be defined as ". . . any formal description, in words, diagrams and/or mathematical equations, of the structure and workings of a system together with unambiguous acceptable definitions of its parts [6:6]."

Care should be taken in expecting too much from models since they are only abstractions and as Kaplan states:

Models can help theory development by raising questions, demonstrating gaps, helping discriminate between the important and the unimportant, generating testable hypotheses, and serving as a vehicle for the communication or comparison of theories [11:428].

The objectives of developing a model to simulate the behavior of the system of interest are two fold:

1) to provide a greater understanding of the existing system and thus provide an aid for problem solving and future decision making.

2) to enable the potential impact of alternative decisions to be evaluated in the light of their effect on the system (6:19).

In relating the first of the above objectives to the policy maker, he must, of necessity have some understanding of the system or domain in which he operates and consequently any aid or model which provides a better understanding of that system must enhance his potential for making better decisions. The techniques of modeling facilitate the second objective by enabling predictions of the impact of possible decisions to be made and quantified instead of relying on experience and subjective judgments. This is not to say that modeling holds all the right answers. The model itself must be a reliable replica of the real world system. The extent of its reliability can only be judged by analyzing the robustness of the model against a variety of

known real world conditions or states. Further, the model only reveals the likely impacts of various decisions. The interpretation of the acceptability or otherwise of the results of the decisions and consequently which decision is ultimately made remains the prerogative of the decision maker. Also the model only demonstrates the interactions and decision impacts within the system boundaries and system components as selected.

Policy implementation within the systems concepts involves making decisions which direct the system towards providing acceptable or desired goal outputs. The system output is monitored for correctness or goal alignment and any deviations from an acceptable standard result in some form of decision leading to corrective action. This sequence of events is limited by the feedback process and is the basis of system dynamics (8:14). The essence of this sequence is the self regulatory aspect of the process which in fact is the feedback loop from output to input of a closed system (8:51-52). In the information feedback system, conditions are converted into information that is used as a basis for decisions that direct control actions in an attempt to alter surrounding conditions (8:61). Feedback systems exhibit behavior as a whole which is not evident from an examination of the separate parts of the system in isolation (8:61). The process is cyclic, and time lags inherent in either the feedback control system and/or the process itself are

extremely important in affecting how the system responds to control. A pictorial view of a closed system involving goals, policy, controls, and feedback is shown in Figure 2-1.

Many analytic techniques are available for the examination of component parts of a system while other techniques show relationships. However, in retaining the system as a whole with all its inherent imperfections, time delays and feedback paths, leaves us with a systems approach as the most realistic and feasible technique (30:42). Beer succinctly sums up the power of the systems approach when he states that it "preserves the relevant structure [8:253]."

This chapter presents a literature review to provide the reader with a historical background of the AADMS, as well as a discussion on the systems approach to problem solving. The specific approach, system dynamics, is discussed in greater detail in Chapter 3.

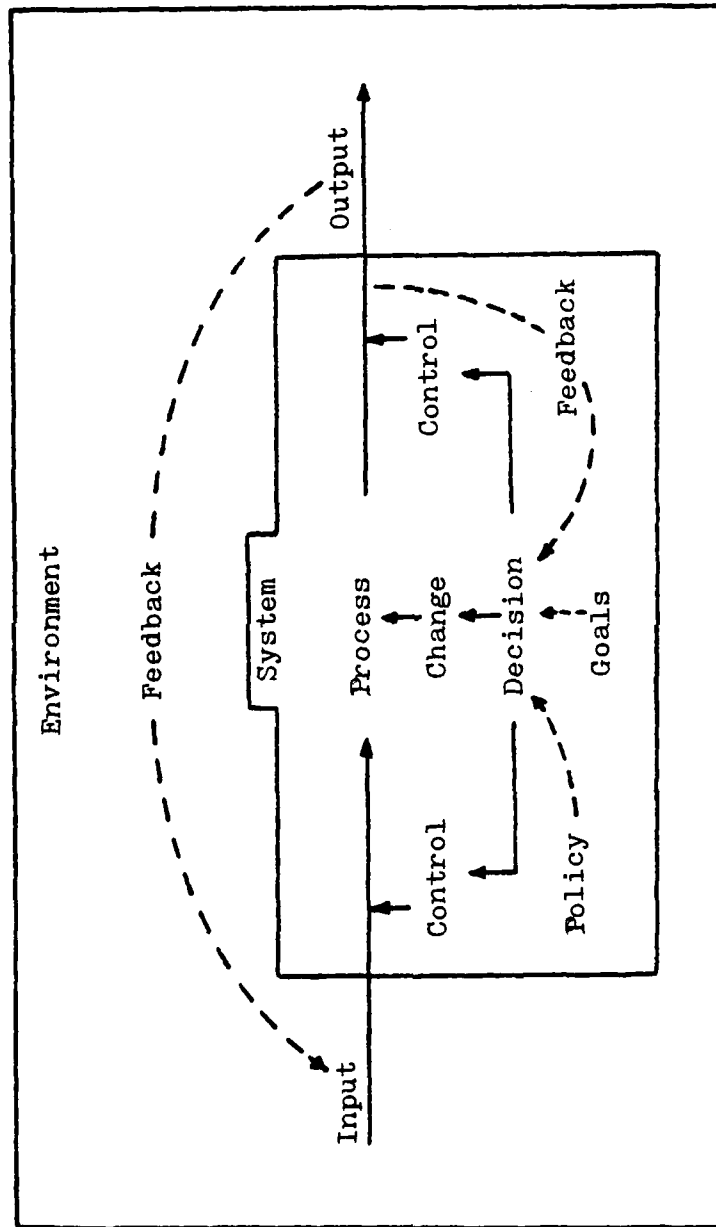


Figure 2-1 Information Feedback System

Chapter 3

METHODOLOGY

Introduction

The broad conceptual framework of the AADMS was identified in Chapter 2. This chapter details the methodology for identifying and quantifying the components of a system in order to construct a system dynamics model. The identification process is necessary to isolate subsystems which in turn must be adequately described and then properly interrelated with each other to construct a model of the system. The system dynamics technique provides an organized sequential methodology to build the model and thereby address the research objectives. The specific application of this research methodology to the AADMS is contained in Chapters 4, 5, and 6.

DEVELOPING THE MODEL

The general description of the system, such as that contained in Chapter 2 is developed from research efforts, documentation, and interviews with key personnel. This description is necessary to form the concept of an overall system structure with interrelated subsystems. Hence, this structure must represent what we understand the true system to be.

Causal Loop Diagram

The causal loop diagram provides a more detailed description of the system variables and the relationship between the variables. Figure 3-1 shows an example of a simple causal loop diagram for the AADMS. The arrows demonstrate links between variables and the direction of the arrow shows the presumed direction of causation. The signs at the heads of the arrows infer the direction of change of the head variable if the tail variable increases.

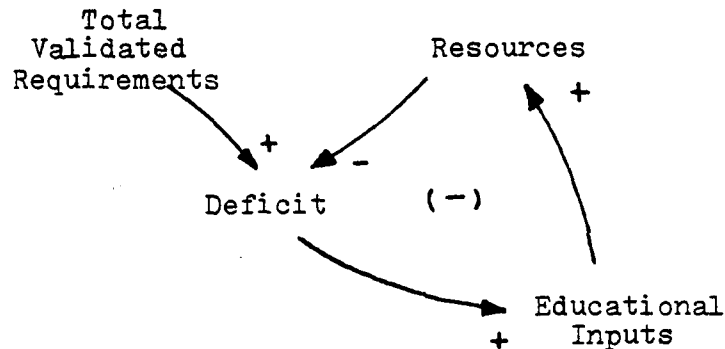


Figure 3-1 Causal Loop Diagram.

The rationale for causal loops is based on conservation considerations: flows out of one variable must flow into one or more other connecting variables. The links between, and respective responses of, variables are obtained by:

- 1) Direct observation and interview
- 2) Instructions or regulations
- 3) Accepted theory
- 4) Hypothesis, Assumption or Belief
- 5) Statistical evidence [6:66-69].

The selection of specific variables, and the extent of the numbers of variables entered in the causal loop diagram (hence the system boundaries), is directly related to meeting the research objectives. Whether or not all necessary important variables have been included, or whether in fact some variables are extraneous to the behavior of the system, is a matter for confirmation during the sensitivity testing process. This progressive building and confirmation process to develop the model in greater detail is the method by which the initial conceptual model is internally validated (8:67).

The dynamic nature of the system is reflected by feedback loops in the causal loop diagram. A feedback loop occurs if it is possible to commence at a variable and follow the direction of the causation arrows through one or more other variables and return to the same starting variable. Feedback loops may be positive or negative. Positive loops, which are characteristic of uncontrolled growth or decay, are identified by an even number of negative links. Negative feedback loops contain a regulating or controlling mechanism, and are identified by an odd number of negative links. Feedback loops are instrumental in determining the behavior of the system over time. Although trends in system behavior can be determined from causal loop diagrams, specific detail as provided by flow diagrams more clearly identifies the variables and the flows between them.

The causal loop diagram shown in Figure 3-1 presents the AADMS in a very general sense. It is evident from this diagram that as validated requirements increase the deficit increases. However, as resources of AAD holders increases, the deficit decreases. Increases in the deficit under normal circumstances result in an increase in educational inputs, which in turn result in an increase in the total resources. A negative, or regulating, feedback loop is formed through the linking of resources, deficit and educational inputs. The next stage of model development is to construct flow diagrams.

Flow Diagrams

Flow diagrams are a higher order of pictorial representation of a system than causal loop diagrams and are designed to represent the basic structure of the system. The system dynamics approach is to model systems as a set of reservoirs or levels, interconnected by controlled flows. The essential features of this approach are levels, flows, decision functions that control the rates of flows, and information channels that connect the decision functions to the levels.

"Levels are the present values of those variables that have resulted from the accumulated difference between inflows and outflows [8:68]." Within the graduate education system, levels include the number of AAD billets, the number of AAD holders, and the number of officers undergoing

graduate education. Levels do not occur only in tangible variables. They can also exist in the information network, such as awareness levels in the minds of decision makers and in information used in decision making.

Flow rates are variables which define the present, instantaneous flows between levels in the system and are determined by decision functions. System dynamics utilizes five basic flow networks -- information, material, money, personnel and capital equipment.

While levels and rates are necessary and sufficient for modeling the system structure, it is common practice to include a third type of variable, called an auxiliary variable. Auxiliary variables are generally used to simplify the equation writing process in situations where a decision function depends on several levels which, if included directly in the decision function, would prove to be cumbersome.

Also found in system dynamics models are parameters, which take on assigned values considered to be constant (at least over the simulated time for a particular model run), and delays, which describe time delays in the flows of information, material, money, personnel and capital equipment.

Decision functions are policy statements or decision rules that determine how available information about levels leads to decisions which control flow rates. Therefore, the result of a decision function is action expressed as flow rates. It should be noted that decision functions

involve both managerial decisions and actions that are "inherent results of the physical state of the system [8:69]." In both cases, decision functions are dependent only on information about levels. Figure 3-2 shows the symbols used in system dynamics flow diagrams. The next phase of model development is to convert to flow diagrams into DYNAMO computer equations.

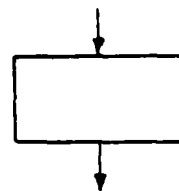
Equations

The equations constitute a mathematical model of the system which, when solved on a computer, will determine the values of the variables of interest over time. Basically, the equations determine system conditions for a new point in time using conditions from the previous point in time. The solution of equations is repeated for small, equal intervals of simulated time until the total desired simulated time span is covered. The equations are a fully quantified representation of the flow diagram.

There are five major types of equations used in modeling the system: level, rate, auxiliary, supplementary, and initial-value equations. The level equations and rate equations are fundamental to system dynamics modeling; the remaining types of equations are intended to add convenience and clarity. Rate equations are models of the system decision functions.

Level, rate, and auxiliary equations all have time dimensions. In running the model on a computer, simulated

Levels



Flows - Information



Material



Orders



Money



Personnel



Capital Equipment



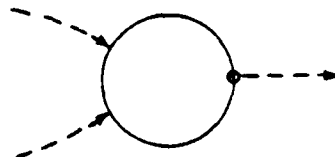
Decision Functions (Rate Equations)



Source/Sink (levels outside the system)



Auxiliary Variable



Parameter



Delay

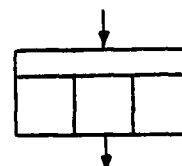


Figure 3-2 Symbols for Flow Diagrams (8:82-84).

time is broken into small intervals of equal length and symbolized as DT . Values of levels, rates and auxiliary variables vary over time and letters are used to include time in the variable name -- "K" denotes the present, "J" denotes the past the "L" denotes the future. The intervals between J and K, and K and L, are each equal to DT . Therefore, at time K (the present), the level equations show how to obtain levels at time K, based on levels at time J, and rates over the interval JK. After the levels have been determined from time K, the rate equations use the values in determining rates that will apply over the forthcoming time interval KL. After rates for the interval KL have been determined, simulated time is incremented by DT . Thus, the K levels are relabeled as J levels, and the KL rates become the JK rates. This process is repeated until the desired total time period has been simulated. Figure 3-3 illustrates the procedure.

Auxiliary equations define auxiliary variables, which were previously described. Auxiliary equations can be dispensed with by including their algebraic content directly into a rate equation. However, this may result in overly complex rate equations or, in some cases, the user may wish to have knowledge of the values of intermediate variables. In these situations, the auxiliary equation is useful. Auxiliary equations are evaluated at time K but after the level equations for time K, because they use the present values

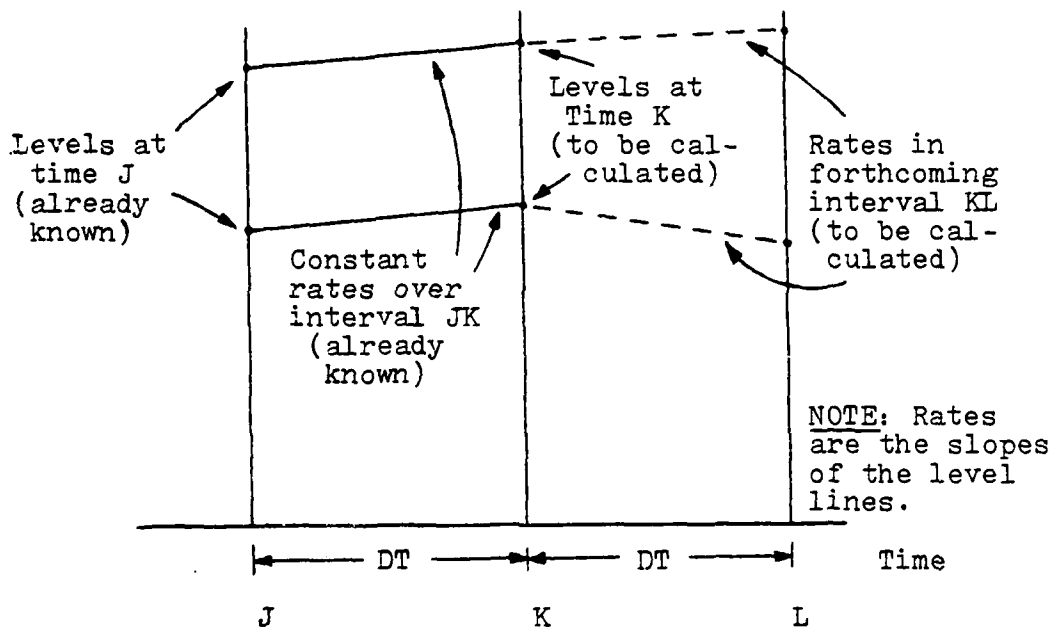


Figure 3-3 Calculation of Levels and Rates at Time K (8:84).

of the levels. Also they are evaluated before the rate equations because their values are used in the rate equations.

Supplementary equations are used to define variables which are not actually part of the model structure but which are of interest to the modeler. Values of supplementary variables are therefore included in the output from the model runs.

Initial-value equations are used to provide the starting point for a model by defining the initial values for the levels and some of the rates.

The equations are written to conform to the DYNAMO computer language. This language was originally developed for use with system dynamics models and is available on the Air Force Logistics Command (AFLC) CREATE system, through the Air Force Institute of Technology (AFIT) computer terminals.

A key point is that all the variables that are needed to adequately model the system must be operationally defined and quantified. For example, the number of AAD holders in a given Air Force Specialty Code (AFSC) is an obviously quantifiable variable whereas congressional attitudes towards graduate education in the Services (which may or may not need to be included in the model) is not obviously quantifiable. Flow diagraming and equation writing are stages of model development that are basically carried out concurrently, and they both require exclusively quantitative variables and mathematically stated decision functions (rate equations). This aspect is discussed further in later paragraphs.

Once the equations have been completed, verification of the equations is required to be undertaken. This involves comparison of the DYNAMO equations with the flow diagram to ensure that the equations accurately represent the relationships depicted.

Collection of Data for
Constructing Flow
Diagrams and Equations

The causal loop diagram represents the initial conceptual model of the system and is used to provide initial direction to the search for data by indicating which variables are likely to be important in modeling the system. Determination of which data are actually needed, corresponding to which variables need to be included in the model, are made by conducting interviews with key decision makers within the system. The interviews provide much of the data needed to build the model. Specifically, the interviews are aimed at obtaining data to be used for:

1. Determining the accuracy of the conceptual model (as depicted in the initial causal loop diagram), and enabling corrections to be made where required.
2. Determining which variables (levels and auxiliary variables) are used by decision makers in specific decision functions, including the nature of the information channels (extent of information bias, delay and distortion).
3. Determining, in operational terms, how decisions are made, to facilitate construction of rate equations.
4. Determining the nature and extent of problems as perceived by system decision makers.

The needs for specific quantitative data in establishing the model become evident during the research and interview phase of data collection.

Development of the model, as described above, shows two major problems from a scientific viewpoint:

1. The problem of operationalizing certain variables that cannot be subjected to interval or ratio level

measurement. For example, the perceived congressional attitude towards graduate education cannot be directly measured using interval or ratio scales.

2. Simulation of the decision making process requires not only that all variables be quantified, but that the decision be depicted as a mathematical equation. From a strictly scientific viewpoint, this cannot yet be shown to be a valid procedure.

To the scientific researcher, such problems may appear insurmountable and, therefore, an outline of the system dynamics approach to the area of policies and decision making appears warranted. Forrester views the decision making process as consisting of three parts:

. . . the formation of a set of concepts indicating the conditions that are desired, the observation of what appears to be the actual conditions, and the generation of corrective action to bring apparent conditions toward desired conditions [8:93]."

The term "policy" is used to describe how the decision process converts information into action. Some policy is very formal, such as that which exists in written orders and directives, while much (possibly most, depending on the situation) is informal, and depends on "habit, conformity, social pressures, ingrained concepts of goals, awareness of power centers within the organization, and personal interest [8:97]."

Forrester claims that, in spite of the impracticality of determining precisely how decisions are made, policy

can be captured, in mathematical terms, with sufficient accuracy to meet the needs of system dynamics modeling (8:97-102). He does stress, however, that assigning numbers to verbal descriptions of decision processes "does not enhance the accuracy of the original statement [8:101]."

Forrester then describes, in very broad terms, how variables that influence decisions can be quantified and placed in equation form to describe the decision function (8:103-108). Major considerations include, for each variable, the direction, magnitude, and shape (linear or curvilinear) of the relationship between input variables and the resulting decision (flow rate). Forrester sums up the importance of including the decision functions as follows:

No plea about the inadequacy of our understanding of the decision-making process can excuse us from estimating the decision-making criteria. To omit decision-making is to deny its presence - a mistake of far greater magnitude than any errors in our best estimate of the process [8:103].

For this research, the aim was to use measurable concepts and surrogate variables to represent those variables which could not be scientifically measured, and to determine rate equations using subjective judgment, supported where possible, by empirical quantitative data. The information gained from interviews is of paramount importance in ensuring that rate equations are adequately defined. Prior to operational use of the model it is important to validate the model.

Model Validation

Forrester states that:

The validity (or significance) of a model should be judged by its suitability for a particular purpose. A model is sound and dependable if it accomplishes what is expected of it [8:115].

The above viewpoint is shared by Coyle and the discussion in this section draws heavily from that author (6:181-184).

Given that the primary objective of developing a system dynamics model is to identify changes to the system which will improve overall system performance, an objective assessment of model validity can only be made by observation of system behavior at some time after the indicated changes are made. A comparison of actual system behavior and system behavior predicted by the model will indicate, post facta, whether the model was valid for predicting the behavior of the system. The problem is that model validity must be ascertained prior to decisions to change the system and, therefore, validation of system dynamic models primarily involves ensuring that one has sufficient confidence in the model to use it for making decisions regarding system changes. To meet this need to develop confidence in the model, Coyle proposes five factors which require consideration (6:182-183):

1. System boundaries. System boundaries must be carefully selected to ensure that all system elements that influence the behavior of interest are included. That is, all variables, parameters, and decision functions that directly or indirectly influence the behavior to be improved must be included. A secondary factor relative to system boundaries is that efforts should be made to exclude those system elements that do not affect the behavior to be improved. Excessive detail adds cost to the modeling exercise and may well obscure behavior of interest.

2. Gross error. The mathematical model should be operated to ensure that no obviously implausible behavior results. For example, negative inputs to graduate education programs are obviously implausible and would indicate an error in the model. Such errors in the model may result from arithmetic mistakes, dimensional errors, and failure to model constraints and decision functions realistically.

3. Model structure. Confidence in the adequacy of the model with regard to structure involves progressively checking, at each stage of model development, that the necessary variables have been included, the interrelationships between variables have been correctly identified, and the decision functions reasonably describe those in actual use.

4. Parameter values. According to Forrester (8) and Coyle (6), the accurate determination of parameter values is usually unimportant initially as parameters can vary over reasonably wide ranges of values without altering the basic dynamic behavior of the system. In any event, the sensitivity of system behavior to parameter values should be tested by conducting sensitivity analysis of the model. Such analysis can be used to determine the accuracy to which parameter values need to be determined to provide the degree of confidence required.

5. Ability of the model to reproduce actual system behavior. Ideally, the model should be tested to determine how closely simulated behavior agrees with observed system behavior. Unfortunately there are usually serious obstacles to the performance of such tests. First, data on system behavior (outputs) are usually difficult to obtain. Also, such data is not meaningful unless data on the system inputs and decision rules that resulted in the observed outputs are also available. Second, the model can provide outputs on many aspects of system behavior. The question then arises as to how many of these outputs must be compared to the real system outputs. Third, even if past data is available, statistical tests available for assessing the degree of agreement between the model and the real system must, at some point, be based on subjectively desired decision rules.

In summary, validity of a system dynamics model can only be considered relative to the purpose for which the model was constructed, and must be based on subjective judgment applied to the five factors discussed above.

The remainder of this chapter contains a discussion of model analysis.

Model Analysis

Model analysis can have several uses:

1. It can show how sensitive the model behavior is to the parameter values used, and thus indicate the accuracy to which parameter values need to be determined.
2. It can show the effects of changes in exogenous parameters on system behavior, providing a measure of the ability of the system to respond to environmental changes.
3. It can show the effects of potential changes to the system. For example, various policy and structural changes can be made to the model to determine the likely impact such changes would have if instituted in the real system.

This chapter has provided a very broad introduction of the system dynamics methodology. Further information on the methodology can be obtained by reference to Forrester (8) and Coyle (6).

Contained in the next chapter is a description of the system and a discussion of initial formulation of the model.

Chapter 4

INITIAL MODEL FORMULATION

Introduction

Described in this chapter is the application of the first two stages of the system dynamics methodology to the research effort. That is, a detailed description of the Advanced Academic Degree Management System and a descriptive model of the system in the form of a causal loop diagram.

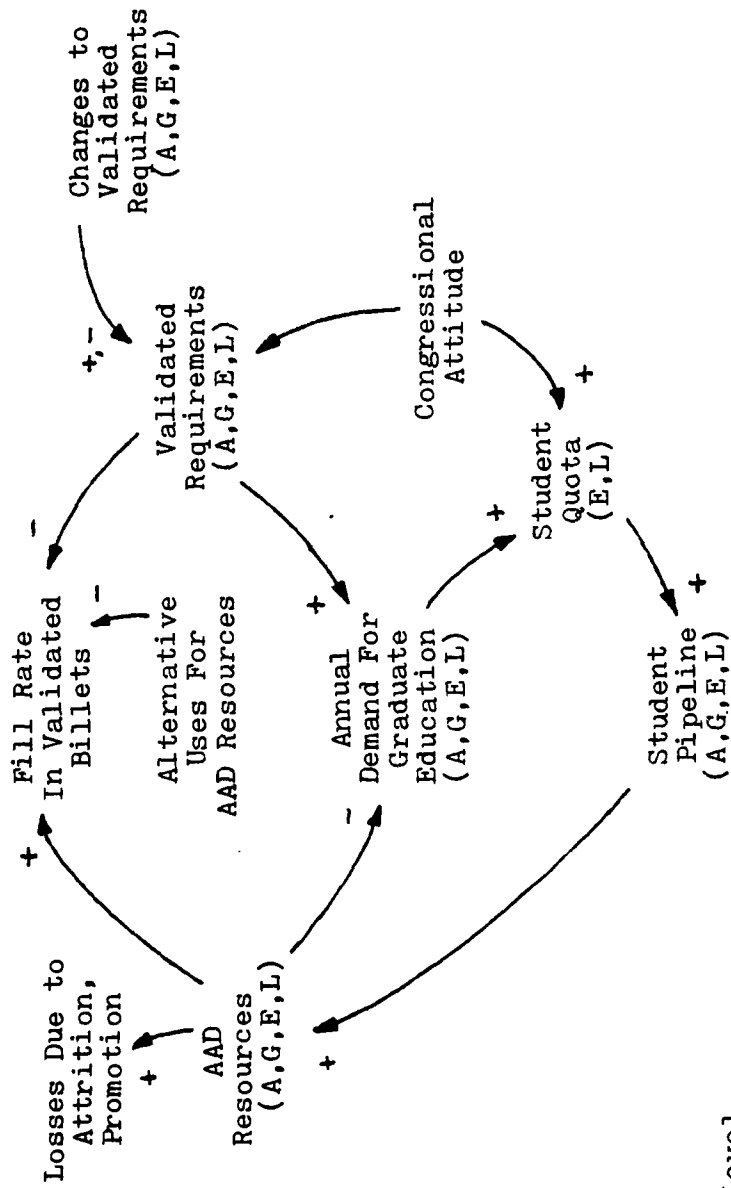
Overview of the System

The system used by the Air Force for managing full-time, fully-funded graduate education involves many people and several functional areas. Basically, the activities conducted within the system are outlined below. Each of these activities is sufficiently discrete to be classified as a subsystem.

1. Identification and validation of those jobs that are perceived as requiring the incumbent officer to possess an AAD.
2. Determination of the number of fully-funded inputs that need to be made annually to educational institutions to ensure that a specified level of AAD qualified officers is maintained.
3. Selection of officers to undergo full-time, fully-funded graduate education.
4. Education of officers at the graduate level.
5. Management of the resources of officers holding AADs.

As noted in Chapter 1, the AADMS has a primary objective of ensuring that "academically qualified officers are available, at all times, to solve Air Force managerial and technological problems [22:1-1]." The basic system structure is presented in the form of a causal loop diagram in Figure 4-1. This elementary structure was determined from information obtained during the literature review phase of the research, including interviews with managers involved in the management of graduate education at AFIT and at HQ USAF (MPPE).

Figure 4-1 shows that the fill rate in validated billets (by officers having the correct AFSC, grade, ASC, and academic level) is determined by the difference between the inventory of AAD resources and the number of validated billets, and by the extent to which AAD resources are assigned to non-validated billets to meet service requirements. The difference between resources and requirements also determines the annual demand for graduate education. That is, shortages of resources are translated into a need for inputs to full-time, fully-funded graduate education programs. The needed inputs are the basis for the final quota, which can be (and, in recent years has been) substantially altered by Congress. It should also be noted that the quota is expressed only in terms of ASC and academic level - AFSC and grade are excluded. The quota is met by the selection



A = AFSC

G = Grade

E = ASC

L = Academic Level

Figure 4-1. Basic System Structure

of people to undergo graduate programs. As real people are selected, the student pipeline is necessarily defined in terms of AFSC, grade, ASC, and academic level. This student pipeline then feeds the level of AAD resources, which is also subject to losses due to promotions and attritions.

Presented in the remainder of this chapter is a description and causal loop diagram for each of the AADMS subsystems.

Determination of Requirements

The identification of positions requiring incumbents with advanced degree education is initially the responsibility of all supervisors of officer positions. Semi-annually, each such supervisor is required to survey all authorized line officer positions under his immediate control (in the grade of colonel and below) to determine whether AAD requirements need to be adjusted. AFM 36-19, Advanced Academic Degree Management System, provides broad criteria to assist supervisors in identifying potential validated billets (22: 4-3, 4-4). This manual also provides guidance based on the career area and Air Force specialty involved. Both the broad and the so-called detailed guidance are, for most positions, imprecise and very much open to interpretation. In essence, the supervisor is required to make a subjective judgment in answering the following questions:

1. Given the skills and knowledge required for successful performance of the job, does the incumbent require advanced academic education?

2. If so, what is the appropriate Academic Specialty Code (ASC) and level of degree required?

Given that there are many supervisors throughout the Air Force who are required to make such decisions, we can postulate that:

1. Individual supervisors' perceptions of both the job requirements (in terms of skill and knowledge) and the appropriate sources of the job requirements (graduate education, continuing education, experience) will vary widely in their quality (closeness to objectivity).

2. In the absence of clearly defined policies, individual situational factors are likely to play an important role in the decision to request, or not request, a validated billet. For example, the desire to obtain the services of a particular officer possessing an AAD could well lead to the necessary AAD request to facilitate the desired assignment. Other factors, such as the desire for status, pressure from superiors, and the success rate of previous requests, appear likely to influence the decision.

Another behavioral factor which appears to play a major part involves the selection of the appropriate ASC. Indications are that supervisors tend to request the less specific ASCs (specified to the two, or perhaps three, digit level), on the basis that with very limited resources in the more specialized fields, the chances of having the billet filled are improved if a more general ASC is approved.

In summary, the initiation of request for changes to validated requirements is made at the supervisory level and is based upon highly subjective information resulting from supervisors' perceptions of two highly complex areas - job requirements (skills and knowledge), and the sources of those skills and knowledge. Also, the leniency of the official policies (decision rules) allows individual and situational

factors to enter the decision process. It should be noted that these decisions form the basis of the AADMS.

The supervisor's assessments of AAD needs are transmitted to the MAJCOM headquarters, through normal channels, on AF Form 1779, which specifies the Air Force Specialty Code (AFSC), grade, desired level of degree (doctorate or masters), ASC, description of duties for the position, and written justification for the AAD requirement. The MAJCOM functional manager is required to review and consolidate requests for new or changed AAD requirements within his career area, and to forward those requests he considers to be valid to HQ USAF. The MAJCOM functional manager is also responsible for forecasting AAD requirements: "These requirements could result from technological change or breakthrough that would necessitate new academic disciplines or increased emphasis in current disciplines [22:3-2]."

As with the supervisory level, decisions made at the MAJCOM level are based on perceived needs. Information on needs perceived at the supervisory level is contained in the AF Form 1779 and this information, combined with information about the nature of validated billets within his area of responsibility, and his perceptions of likely future requirements, will be the basis for his decision as to whether to forward the request for the validated billet to higher authority.

Although there are less MAJCOM managers than supervisors, there are sufficient to indicate that individual

and situational factors will play an important role in the decision, and that the degree to which this is true is again a function of the leniency of published policies.

At HQ USAF, functional managers and career area panels of officers appointed by the functional managers, review and approve (validate) or disapprove of requested changes to AAD requirements within their career area. The panels are required to comprise "at least two highly qualified officers with backgrounds and experience" in the appropriate career area (22:2-2). The HQ USAF functional managers and career area panels are constrained in the number of validated billets that they can approve by ceilings which are set by the Air Force Education Requirements Board (AFERB). The ceilings are generally current for two years (the period between scheduled AFERB meetings). Once the ceiling is reached, new requirements in the career area can be met by deleting existing billets or, if this is infeasible, by requesting that the AFERB increase the ceiling.

The ceilings set by the AFERB are logically affected by the attitude of Congress to the Air Force graduate education program - as Congress' attitude improves, the ceilings will increase, and vice-versa. In fact, despite the subjectivity of information at all levels, and the imprecision of the relevant policies, the major determinant of the level of validated requirements in recent years appears to have been Congressional pressure to keep the numbers down.

Evidence of Congressional pressure in this area was provided in the report on the Fiscal Year 1979 DOD Appropriations Bill by the House Committee on Appropriations. The Committee directed that DOD report to Congress on its (DOD's) plans for reviewing the validation process "with a view toward significant reductions [18:29]." The consequent report provided to Congress showed that the number of Air Force validated billets had been reduced from 11,251 in FY 1975 to 9,009 in FY 1979, "in the face of increasing technological demands. . . [27:II-4]." The same report also stated that the Air Force guidelines and criteria on designating validated billets were being made more detailed. This relationship is also logical and is reflected in the causal loop diagram at Figure 4-2.

Congressional attitude to the overall AADMS appears to be related to the perceived degree of subjectivity in the requirements determination process, the utilization rate of the Air Force Institute of Technology (AFIT), and the management of AAD resources (19:24-30). With regard to the requirements determination sector, the attitude of Congress appears to be affected by such factors as the leniency of the criteria and the absolute number of validated billets. It should be noted, however, that these are not the only factors and it is very probable that factors outside the AADMS would also have an influence, such as overall attitude toward military spending.

In summary, the determination of graduate education needs is based on a hierarchical set of identification, review, and validation processes, with the AFERB setting limits on the numbers that can be approved in each career area. Each level of the Air Force structure makes decisions based on perceived needs and, to the extent that the official decision rules are ill-defined, behavioral factors probably have a relatively large influence. Congressional pressure appears to be having a major influence on the overall level of validated billets and on efforts (not yet brought to fruition) to improve the quality of the guidelines/criteria for identifying and approving validated billets.

Figure 4-2 shows a causal loop diagram of the requirements determination subsystem and reflects the elements identified in the foregoing discussion, and their inter-relationships.

Determination of Annual Education Input Quotas

Annual quotas for inputting students to full-time, fully-funded graduate education programs are determined by HQ USAF (MPPE). In theory, the process involves the following steps:

1. For each AFSC, ASC, academic level, and grade combination, a resource objective is determined by multiplying the current number of validated billets by a manning factor (currently 1.6). The manning factor is supposed to allow for the non-availability of some AAD holders to serve in validated billets, at any given time, due to career development and other manpower management requirements.

2. For each AFSC, ASC, academic level, and grade combination, a five-year resource projection is carried out. The projection attempts to show the resource levels that would exist in five years if no further inputs were made into full-time, fully-funded graduate education programs. Details on this projection are given in Chapter 6.

3. The resource objective is compared with the projected status to provide a five-year shortfall. The shortfall is expressed only in terms of ASC and academic level - the grade and AFSC information is omitted.

4. The five-year shortfall is divided by three to provide the quota for the ensuing fiscal year.

5. Authorization of funds to meet the costs of the projected program are requested, through the budget system, from Congress. On receipt of funding authority, steps 1 to 4 are repeated to "fine tune" the quota, which is then sent to the Air Force Manpower and Personnel Center (MPC) to enable selection activities to commence.

Overlaid on the theoretical decision structure of the quota determination subsystem are several constraints which conspire to reduce the quality of quota decision making. First, the setting of quotas is strongly influenced by direct requests from HQ USAF functional managers for specific inputs to be made - often in areas for which no validated requirements exist. The exact nature of this information input could not be determined but it is known to have a very substantial impact on the final quota.

Second, the current Congressional dissatisfaction with the program has meant that Congress is currently approving funding necessary to meet only about one half of the projected annual quota needs. Under these circumstances, pressures have been generated, at the Air Staff level, to

give preference to meeting scientific and technical requirements, at the expense of other academic areas. This pressure is aided by the need to maintain high utilization of resident graduate programs conducted by the Air Force Institute of Technology (AFIT) - also due largely to recent Congressional pressure.

Another factor to be considered in setting quotas is the availability of officers who are academically eligible, willing to undertake the education (and the attendant return of service), and available (as determined by AFMPC). According to HQ USAF staff, this factor would limit inputs to about 700 annually. Since the most recent projection (March 1980) shows a need for about 1200 inputs in fiscal year 1981, this factor could become dominant in the event that funding restrictions are withdrawn.

Figure 4-3 shows a causal loop diagram of the subsystem for the determination of annual student quotas, based on the above description of the subsystem. This diagram also shows how aggregations are made across the AFSCs and grades to result in a quota expressed only in terms of ASC and academic level. This approach to quota setting is used despite the fact that resources, resource objectives, and projected deficits are accounted for by AFSC, grade, ASC, and academic level.

As well as affecting the projected deficit, the level of AAD resources effects the fill rate for validated

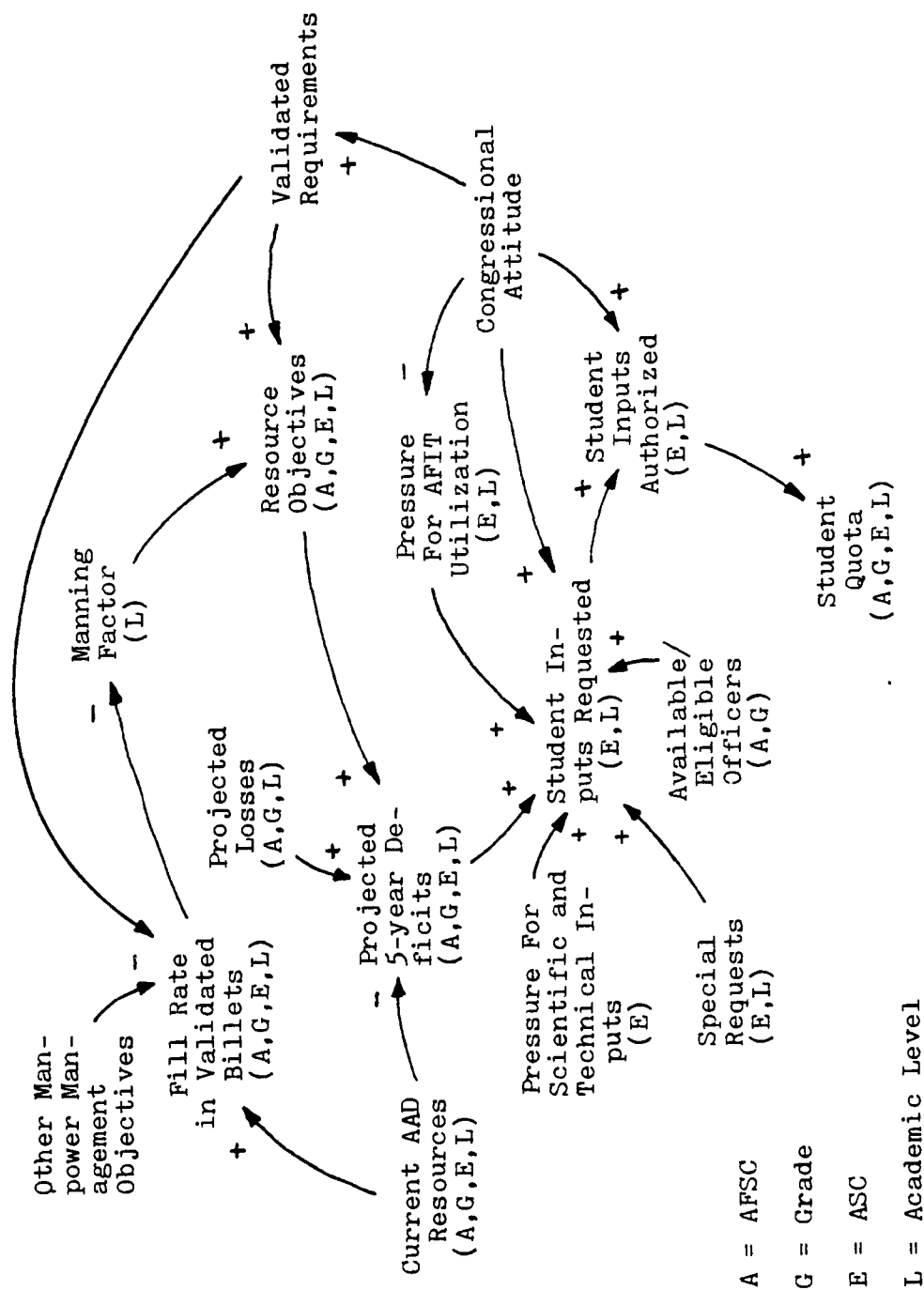


Figure 4-3. Determination of Annual Quotas Subsystem

billets, and this fill rate directly affects the manning factor. Thus, an increase in AAD resources can reduce the projected deficit both directly and indirectly, although the effect via the manning factor is considerably delayed.

Congressional attitude can be seen to be having a three-pronged effect, with pressure to fill AFIT potentially influencing the ASC distribution of the quota, a behaviorally oriented effect with the voluntary reductions in the number of inputs requested, and a direct effect through the funding process.

Selection of Officers to Meet Quotas

The Air Force Manpower and Personnel Center (AFMPC) is responsible for the selection of officers to undergo full-time, fully-funded graduate education to meet quotas provided by HQ USAF (23:7). It should be noted that the quotas specify only ASC and academic level - not grade or AFSC. AFIT is responsible for establishing academic prerequisites and for screening officers' academic records to develop a complete listing of all officers (below the rank of lieutenant colonel) who are academically eligible for selection to the specific programs implied by the quota (23:7). The lists of academically eligible officers are then forwarded to AFMPC where further screening takes place to determine those officers who are available. From the pool of officers who meet the eligibility/availability criteria (for details

of the criteria see AFM 50-5 Vol 1 Chapt 4, USAF Formal Schools Catalogue(24)), inputs to AFIT programs are selected for the following fiscal year.

In theory, the selection process is

highly competitive and considers overall academic and military performance and post-AFIT assignment suitability. Factors include promotability, career progression, prior academic and assignment experience, and the qualifications of the individual to perform in positions requiring the education to be obtained through AFIT [24:4-15].

In practice, AFMPC has experienced considerable difficulty in recent years in filling the quotas provided by HQ USAF - despite the fact that the quotas do not specify a grade. Thus, as previously mentioned, the availability of officers to undergo graduate education is becoming a key constraint on the system and, in the absence of Congressional funding limitations, it would probably drive the system.

One factor which is not listed officially is the "desire" of the system to select as many junior captains and lieutenants as possible. Apparently this policy stems from the fact that by the time a junior captain or first lieutenant completes his education and pay-back time he will be approaching 8-10 years of service and will be more susceptible to remaining in the Air Force. Under the current conditions (i.e., a relative shortage of available officers), this policy is having little effect, and a large proportion of the selectees are second lieutenants.

Leaving aside the relatively unchanging, ongoing constraints on availability/eligibility of officers for input to AFIT, three factors currently appear to be having a relatively large impact:

1. The recent reductions in the size of the rated supplement, entry to which is often via an AFIT graduate education program, have reduced the pool of available/eligible officers.

2. The willingness of officers to apply for or accept full-time, fully-funded graduate education appears to be dropping.

3. The academic qualifications held by officers, which affect their eligibility to enter AFIT programs, appear to be poorly matched to requirements in many academic areas.

Although little or no research has been carried out to determine how these factors are changing, or just what impact they are having on the size of the pool of available/eligible officers, qualitative indications are that they are acting to reduce MPC's flexibility in the selection process.

A causal loop diagram of the selection subsystem is shown in Figure 4-4.

The Education Process

The Air Force Institute of Technology (AFIT) is responsible for conducting and administering advanced academic degree programs to meet the requirements of the AADMS. Thus AFIT conducts resident graduate programs in its School of Engineering and School of Systems and Logistics, and administers fully-funded Air Force students who are attending graduate degree programs full-time at civilian institutions.

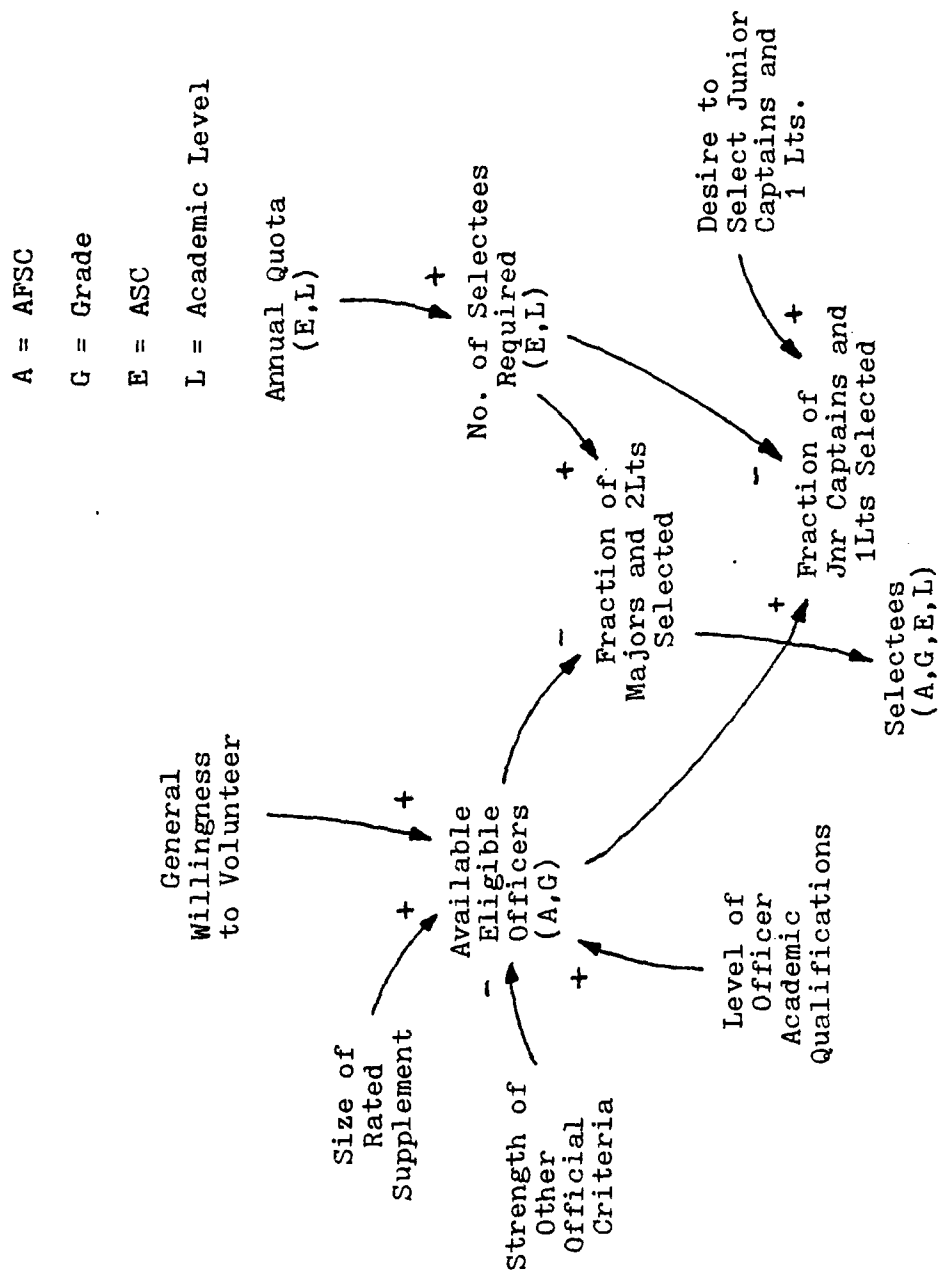
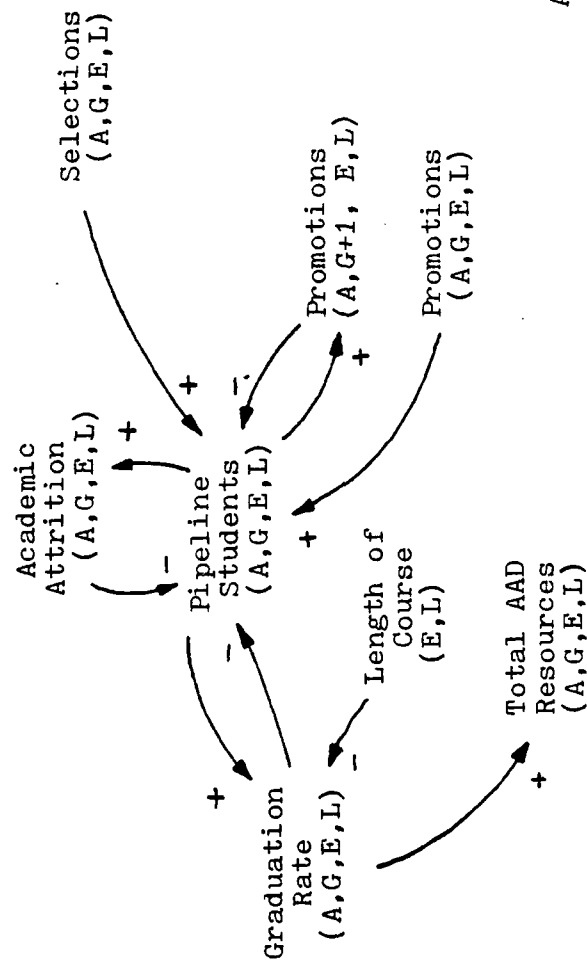


Figure 4-4. Selection of Student Inputs Subsystem

While the education process has important implications for the overall success of the AADMS, a major information network is involved in this area alone and an analysis of this process was considered beyond the scope of this research effort. However, one area is important from an overall system perspective: the utilization (fill rate) of the AFIT resident schools. This factor has become increasingly important in recent years as Congress has progressively cut funds for full-time graduate education in the Services, while insisting that AFIT be highly utilized. Discussions with HQ USAF (MPPE) staff indicated that programs being conducted by AFIT are being given priority in the setting of quotas, although the precise impact of this input is not known. In any event, the inclusion of this factor in the quota-setting process implies that the system is being required to meet an objective (to achieve high utilization of AFIT) that may not be consonant with overall system objectives in times of fiscal constraint.

The causal loop diagram for the education process subsystem is relatively simple and is presented in Figure 4-5. The diagram shows that the number of students in the pipeline, for each combination of grade, ASC, and academic level, is determined by selection rates and graduation rates, with the graduation rate being determined by the number of students in the pipeline, and the duration of the course - which can vary dependent on the ASC and the academic level.



A = AFSC

G = Grade

E = ASC

L = Academic Level

Figure 4-5. Education Process Subsystem

The pipeline level can also be reduced by academic attrition, which appears likely to vary with ASC (the field of study) and the academic level. The other pipeline adjustments result from promotions - promotions are effectively a loss to the grade from which the promotion was made, but constitute a gain for the grade into which the officer was promoted. The number of promotions that will be encountered in the pipeline is, in turn, a function of the number of students.

The Assignment Process

MPC is required to assign graduates of fully-funded programs to a validated billet as soon as practicable after completion of schooling, and not later than the second tour after completion. The policy encourages as many subsequent utilization tours as service requirements and career development will allow and a minimum of two tours in a validated billet is considered desirable.

But these objectives were established as a result of Congressional dissatisfaction with the poor utilization of AAD resources who had gained their degrees through fully-funded programs. The real objective of MPC in relation to the AADMS is, or should be, to fill validated billets with officers of the correct AFSC, grade, ASC, and academic level. However, given other MPC objectives related to manpower management and career development (with which the AADMS objectives must coexist and which the previously mentioned

manning factor is supposed to allow for), MPC apparently has insufficient AAD resources of the correct AFSC, grade, ASC, and academic level from which it can draw to satisfy requirements. The result has been that only about 53 percent of all Air Force validated billets (4,400 out of 8,400) are filled by appropriately qualified officers, despite the fact that a comparison of validated requirements to AAD resources showed that for approximately 8,400 validated billets there were 7,830 officers having the correct ASC. The comparison further showed that about 7,500 officers possessed both the correct ASC and AFSC.

Essentially, the AADMS must provide the AAD resources with the right combinations of AFSC, grade, ASC, and academic level, and in quantities determined by a realistically derived manning factor that will enable MPC's other objectives to be met concurrently with fulfillment of its AADMS objectives.

A causal loop diagram representing the assignment process as it relates to the AADMS is presented in Figure 4-6. The causal loop diagram shows that the rate at which validated billets can be filled is dependent upon the validated requirements and the AAD resources, but indicates that the matching of resources to requirements depends upon the AFSC, grade, ASC, and academic level. The relative weights of the AADMS and other objectives should normally remain relatively stable in peace time and, if a change

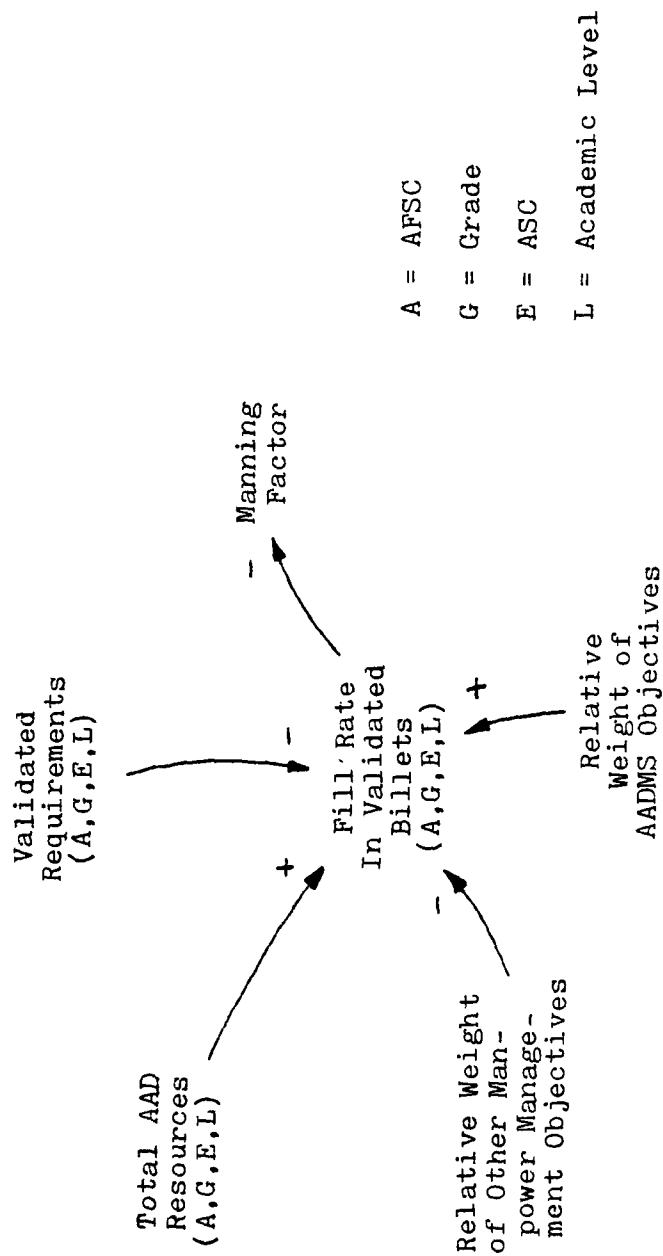


Figure 4-6. The Assignment Process

occurs, the manning factor should be adjusted to account for reduced fill rate or surplus of AAD resources.

Review of the Current System

The system used by the Air Force for the management of full-time, fully-funded graduate education comprises the following activities or processes:

1. Identification and validation of AAD requirements (by AFSC, grade, ASD, and academic level).
2. Determination of annual student quotas (by ASC and academic level).
3. Selection of officers to meet annual quotas (by AFSC, grade, ASC, and academic level).
4. Education of students (by ASC and academic level).
5. Management of AAD resources (by AFSC, grade, ASC, and academic level).

The next chapter will address the development of the system dynamics flow diagrams and equations.

Chapter 5

DEVELOPMENT OF THE MATHEMATICAL MODEL

Introduction

Described in this chapter are the processes involved in transforming the causal loops and information flows, discussed in the previous chapters, into flow diagrams and mathematical equations. The flow diagrams represent, in much greater detail, the composition of the elements of the system and their respective relationships, which when viewed as a whole, demonstrate the structure of the system.

The causal loop diagrams contained in Chapter 4 have been segregated into smaller understandable sectors. These sectors are displayed as flow diagrams and are accompanied by the respective Dynamo computer equations and a description of the processes being undertaken. The flow diagrams show appropriate levels, rates and auxiliaries and contain a variable name.

The equations associated with the flow diagrams represent the nature and magnitude of the relationships between the variables. The relationships and the parameter values are a result of the research of published and unpublished material, current Air Force stated policies, and interviews conducted with managers of various parts of the AADMS.

During this phase of model formulation it was decided that the criterion of system performance would be the ratio of resources to validated requirements, by grade and ASC. Thus, only the masters degree academic level was included, and the AFSC dimension was not considered. The reasons for this decision were:

1. Masters degree level resources and requirements appeared to be subject to less management attention and yet they comprise by far the greater proportion of total AAD resources and requirements.

2. Initial research indicated that grade mismatch was a greater factor in the inability of the system to fill validated billets than was AFSC mismatch.

3. Once developed, the model could be modified with relative ease, by the expansion of the arrays from two dimensions to three or four dimensions to facilitate the tracking of academic level and AFSC.

It should be noted that at various stages throughout the system, aggregations occur, either by ASC or grade. The overall flow diagram developed from the causal loop diagrams shown in Chapter 4 is shown in Figure 5-1. This flow diagram does not contain all the elements developed for the causal loop diagrams due to a deliberate effort to simplify the mathematical model. Research of certain variables indicated that subjective rather than quantitative measures existed and hence these variables were treated as exogenous test inputs. The discussion contained in Chapter 4 relating to how validated requirements are formulated is an example of such a variable. Another is Congressional attitude, the

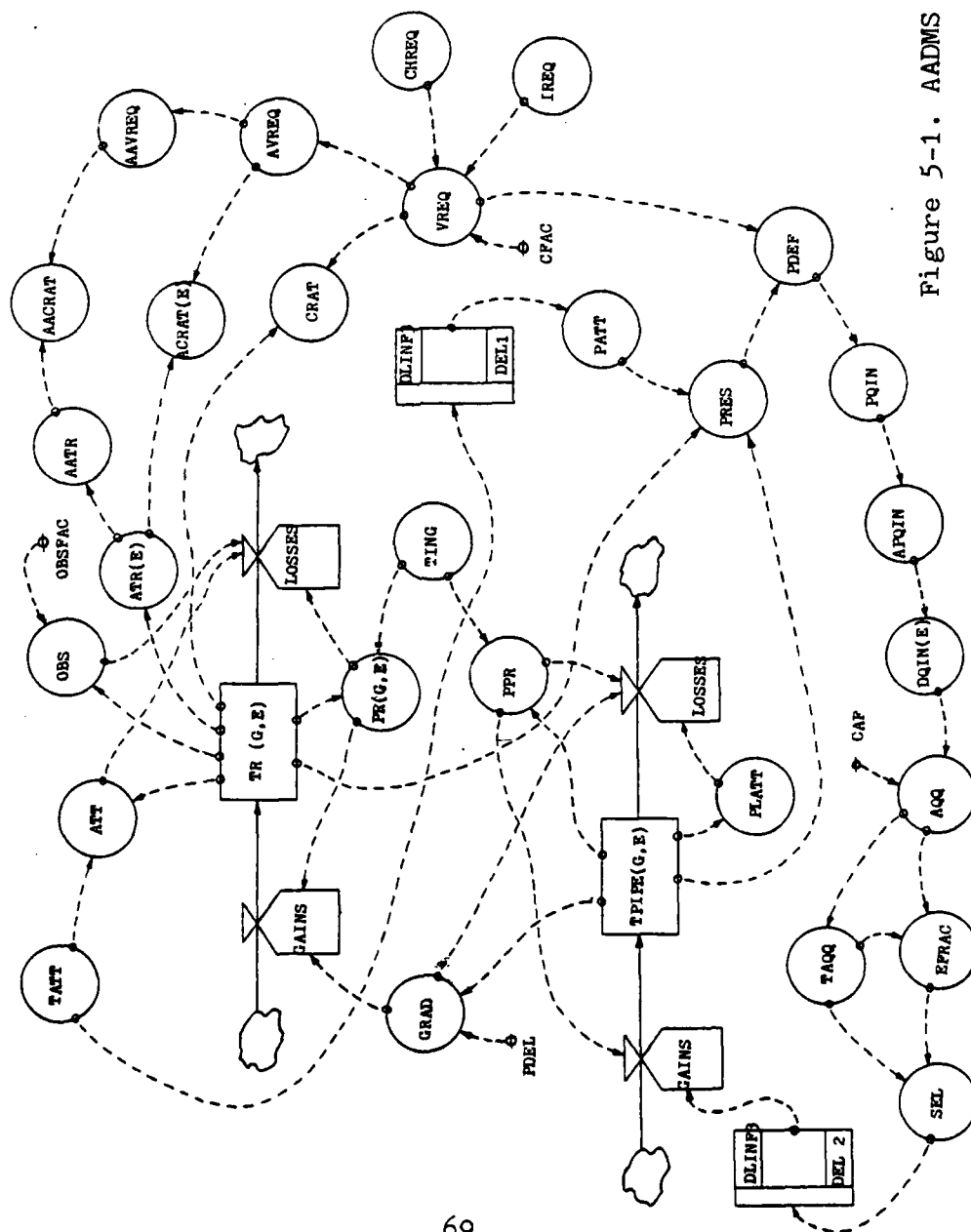


Figure 5-1. AADMS Flow Diagram.

measure for which was taken to be the proportion of slots of AAD education required by the Air Force actually approved by Congress.

The complete AADMS flow diagram (Figure 5-1) has been subdivided into the following sectors:

1. Total Resource Sector
2. Resource Losses Sector
3. Resource Gains Sector
4. Education Pipeline Sector
5. Projected Five-year Deficit Sector
6. Projected Inputs, Authorized Quota, and Selection Sector.

The remainder of this chapter contains discussion of the composition and formulation of the sectors and corresponding flow diagrams, as well as the mathematical equation developed for each sector.

Total Resources Sector

The total resources of officers (TR), by grade and ASC, is represented in Figure 5-2. The total resource may be increased by gains (GAINS) or reduced by losses (LOSSES). The initial value for the total resources equals the coverage factor (CFAC) multiplied by the total validated requirements (VREQ). As the system moved through simulated time the coverage ratio (CRAT) of resources to requirements was monitored by both grade and ASC. At the same time both coverage ratios by ASC (ACRAT) and an overall coverage ratio (AACRAT) regardless of ASC or grade, were monitored.

The aim of the coverage factor was to provide a sufficient number of AAD holders throughout the Air Force

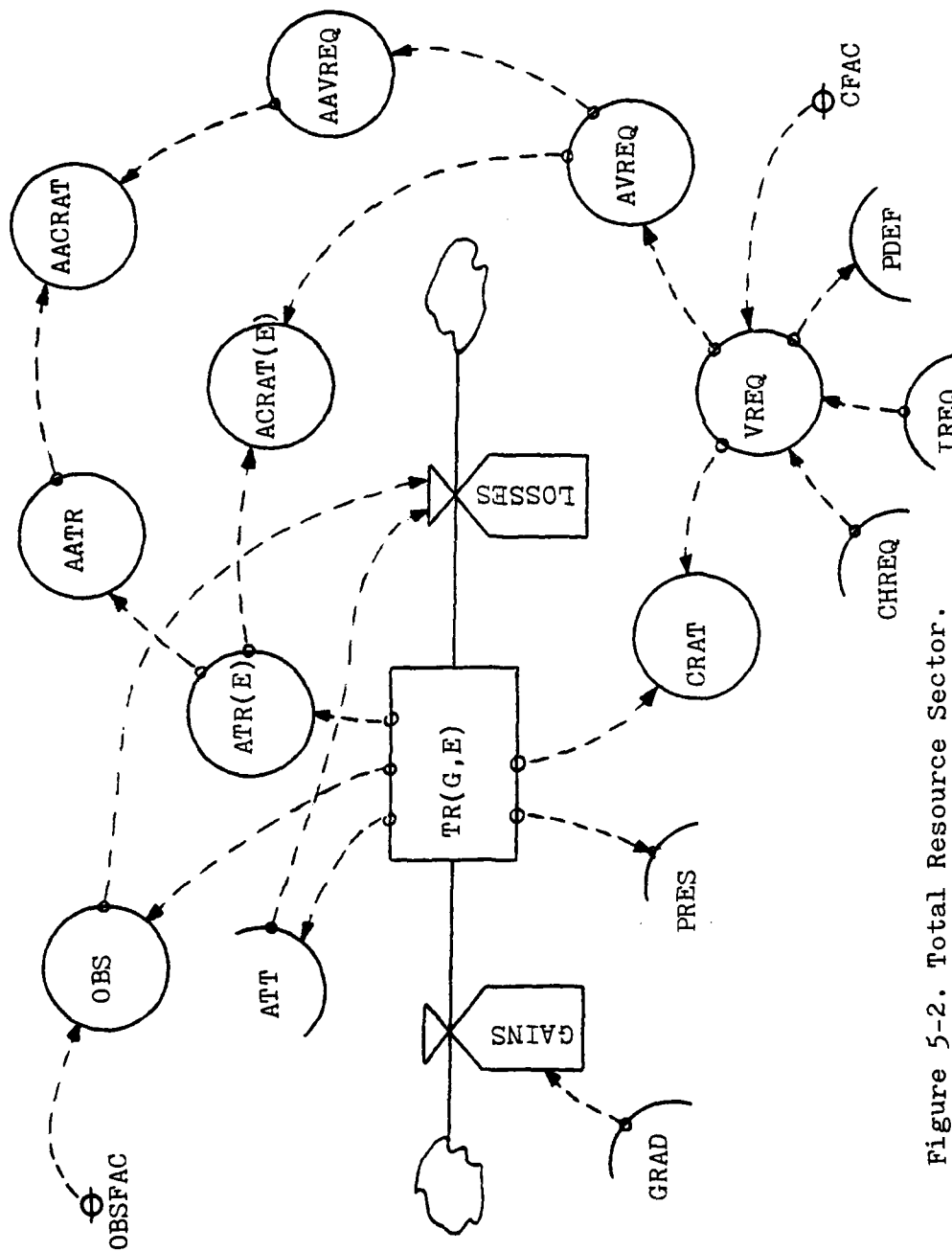


Figure 5-2. Total Resource Sector.

such that special assignments and career development considerations for AAD holders can be undertaken while still having sufficient holders available to fill validated billets.

The set of equations relating to the Total Resources Sector is given below:

TOTAL RESOURCES BY GRADE AND ASC
 $TR.K(G,E) = TR.J(G,E) + DT * (GAINS.JK(G,E) - LOSSES.JK(G,E))$
 $TR(G,E) = CFAC * VREQ(G,E)$
 $ATR.K(E) = SUMV(TR.K(*,E), 1, GRADES)$
 $AATR.K = SUM(ATR.K)$
 $CRAT.K(1,E) = 0$
 $CRAT.K(2,E) = (TR.K(1,E) + TR.K(2,E)) / (VREQ.K(2,E) + .0001)$
 $CRAT.K(GP,E) = TR.K(GP,E) / (VREQ.K(GP,E) + .0001)$
 $ACRAT.K(E) = ATR.K(E) / (AVREQ.K(E) + .0001)$
 $AACRAT.K = AATR.K / AAVREQ.K$

Resource Losses Sector

Total resource losses Figure 5-3 are made up of three components; losses through attrition (ATT), losses through obsolescence (OBS), and losses from each grade through promotion (PR) into the next higher grade. The effect of promotion from a particular grade is a net loss for that grade and a net gain for the subsequent grade. The exception to this loss-gain flow through the grades occurs at the lieutenant colonel level, where any losses are considered lost to that grade and the total system. At the commencement of the grade structure, promotions into the grade of second lieutenant are considered zero. The promotion rate into each subsequent grade is taken to be the total resources at the previous grade less attritions from the

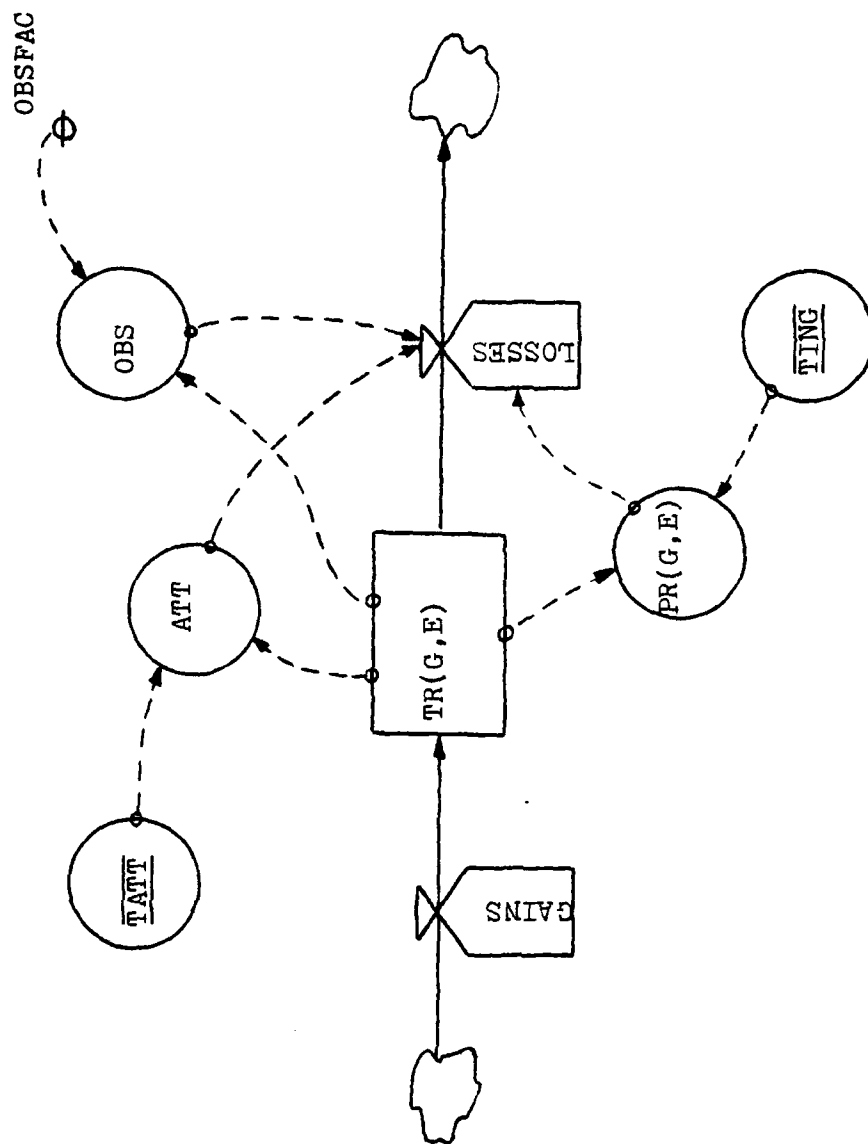


Figure 5-3. Resource Losses Sector.

previous grade: this net resource is then divided by the time in grade (TING) for the previous grade.

Attritions, for whatever reason, occur at all grades. A table for attrition based on historical data using a past five year moving average has been used to emulate the current USAF policy of applying attrition rates to resources of AAD holders.

The third form of losses of AAD holders is through obsolescence. To date, obsolescence has not been considered a factor in reducing the effective usable resource of AAD holders, however, the obsolescence factor has been included to test the reality and subsequent effect on the total resource of AAD holders. The equations relating to the Resource losses sector are presented below.

RESOURCE LOSSES

$LOSSES.KL(GO,E) = ATT.K(GO,E) + PR.K(GO+1,E) + OBS.K(GO,E)$
 $LOSSES.KL(GRADES,E) = ATT.K(GRADES,E) + PRCOL.K(E) + OBS.K(GRADES,E)$
 $OBS.K(G,E) = TR.K(G,E) * OBSFAC$
 $OBSFAC = .02$
 $ATT.K(G,E) = TR.K(G,E) * TATT.K(G)$
 $TATT.K(1) = .0195 * ARCF.K$
 $TATT.K(2) = .0195 * ARCF.K$
 $TATT.K(3) = .1095 * ARCF.K$
 $TATT.K(4) = .008 * ARCF.K$
 $TATT.K(5) = .023 * ARCF.K$
 $ARCF.K = 1 + ACON * TIME.K$
 $ACON = 0$
 $PR.K(1,E) = 0$
 $PR.K(G2,E) = (TR.K(G2-1,E) - ATT.K(G2-1,E)) /$
 $TING(G2-1)$
 $TING(*) = 6/8/32/16$
 $PRCOL.K(E) = (TR.K(GRADES,E) - ATT.K(GRADES,E)) * .0348$

While losses are depleting the pool of total resources of AAD holders, resource gains through graduation of new AAD holders attempt to restore the balance.

Resource Gains

The gains into the total resources (TR) of AAD holders are made up of graduations (GRAD) from the training pipeline as well as promotion (PR) of AAD holders into a grade from the previous grade (Figure 5-4). The graduation rate from the training pipeline is derived through dividing the total number in the pipeline (TPIPE) by the mean pipeline course duration (PDEL) which has been considered a constant value of 6 quarters (applicable to MS degrees in engineering). The gains to the total resource via promotions (PR) is related to the number of resources in the previous grade and the mean time in grade (TING) for that same previous grade. Hence, the previously described losses of AAD holders from a grade through the promotion process results in a gain of AAD holders for the subsequent grade. The equations relating to the Resource Gains sector are presented below.

RESOURCE GAINS

$$\text{GAINS.KL}(G,E) = \text{GRAD.K}(G,E) + \text{PR.K}(G,E)$$

EDUCATION PIPELINE FLOW

$$\text{GRAD.K}(G,E) = (\text{TPIPE.K}(G,E)) / 6$$

The gains from the educational process are discussed in the next section.

Education Pipeline Sector

The total number of potential AAD holder resources (TPIPE) is represented by the training pipeline for eligible

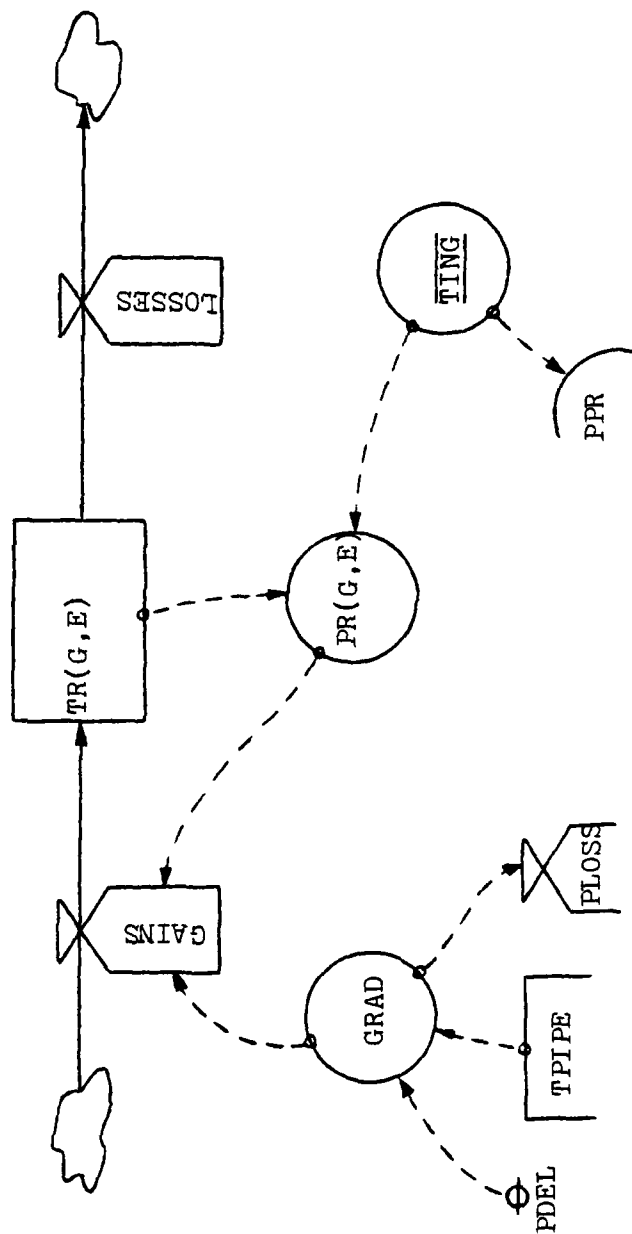


Figure 5-4. Resource Gains Sector.

officers (Figure 5-5). The level of the pipeline may be increased by gains to the pipeline (PGAIN) and reduced by losses (PLOSS) from the pipeline. The initial number in the pipeline has been taken to be the number of 1979 inputs by grade to the respective AFIT resident courses as designated by ASC. The gains to the pipeline result from a third order delayed selection process (DLINF3) as well as promotions (PPR) into each grade while the officer is still in the pipeline. Training pipeline losses are made up of three components. The first of these is the pipeline attrition (PLATT) which is related to the average course noncompletion rate. This rate (FAIL) includes academic failures as well as noncompletion for any other reason. The second component of training pipeline loss is through graduation (GRAD) out of the pipeline into the total resource level. The third form of loss relates to loss from a specific grade by promotion (PPR) into the subsequent grade. This promotion rate is the same as previously described for the total resources. That is, the net resources available in the training pipeline divided by the time in grade for the previous grade. The equations relating to the education pipeline are presented below.

EDUCATION PIPELINE LEVEL

$$\begin{aligned} \text{TPIPE.K9G,E} &= \text{TPIPE.J(G,E)} + \text{DT} * (\text{PGAIN'.JK(G,E)} \\ &\quad - \text{PLOSS.JK(G,E)}) \\ \text{TPIPE(G,E)} &= \text{TPIPI(G,E)} \\ \text{TPIPI(*,1)} &= 40/31/40/7/0 \end{aligned}$$

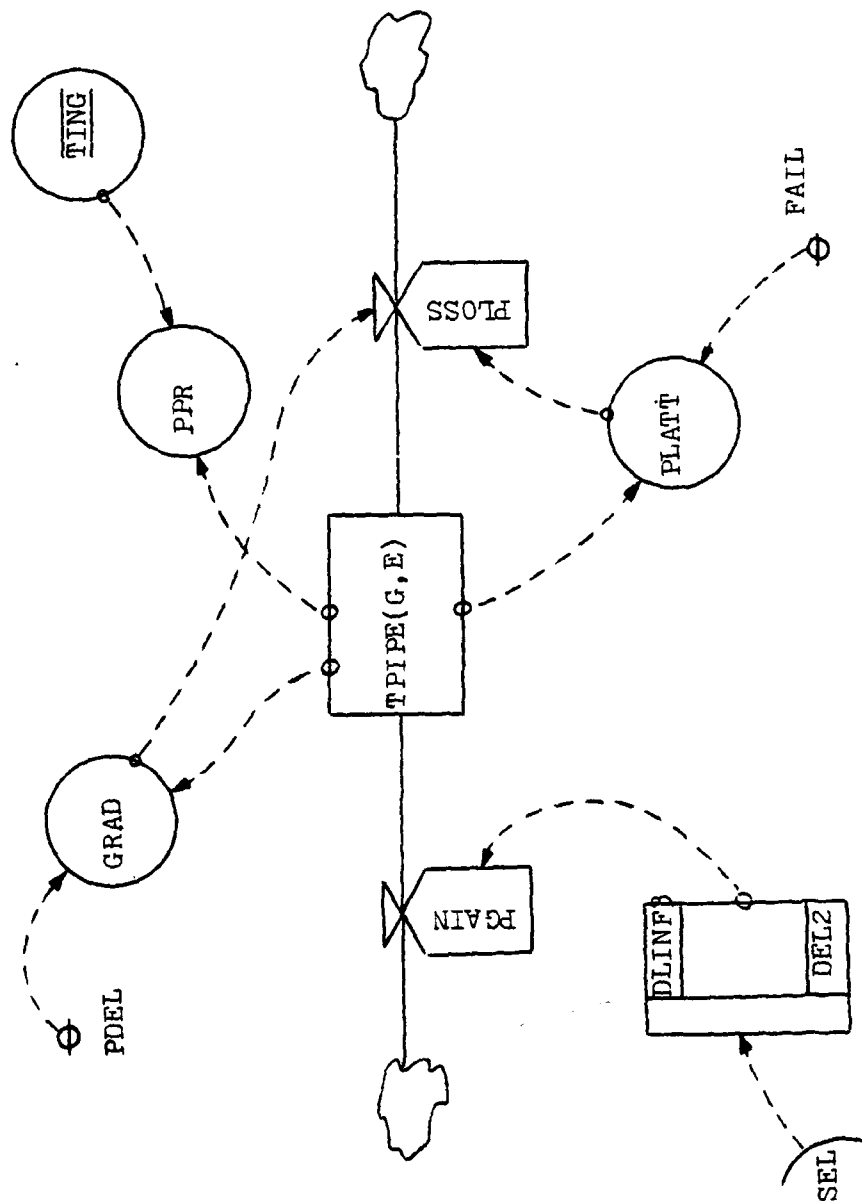


Figure 5-5 Education Pipeline Sector


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PGAIN.KL(G,E)=DELAYP(SEL.K(G,E),DEL2,SPIPE.K(G,E))
+PPR.K(G,E)
DEL2=2.5
PLOSS.KL(GO,E)=PLATT.K(GO,E)+GRAD.K(GO,E)+PPR.K(GO+1,E)
PLOSS.KL(GRADES,E)=PLATT.K(GRADES,E)+GRAD.K(GRADES,E)
PLATT.K(G,E)=(TPIPE.K(G,E)-GRAD.K(G,E))*FAIL
FAIL=.009
PPR.K(1,E)=0
PPR.K(2,E)=(TPIPE.K(1,E)-PLATT.K(1,E)
-GRAD.K(1,E))/TING(1)
PPR.K(3,E)=(TPIPE.K(2,E)-PLATT.K(2,E)
-GRAD.K(2,E))/TING(2)
PPR.K(4,E)=0
PPR.K(5,E)=0

```

The numbers to inject into the educational pipeline are related to the projected five-year deficit which is discussed in the next section.

Projected Five-Year Deficit Sector

The flow diagram for this section is shown in Figure 5-6. The projected deficit (PDEF) is calculated by multiplying the validated requirements (VREQ) by the coverage factor (CFAC) and then subtracting the projected resources (PRES). Currently, forecasts of future changes in validated requirements are not modeled by HQ USAF. The flexibility to model proposed or predicted changes of requirements (CHREQ) has been included to test the potential impact on the system of such changes.

The projected resources are taken to be the total current resources (TR) plus those resources currently in the training pipeline (TPIPE) less the projected attritions (PATT). The projected attritions for five years equals twenty times the quarterly attritions (TATT). The so called projected

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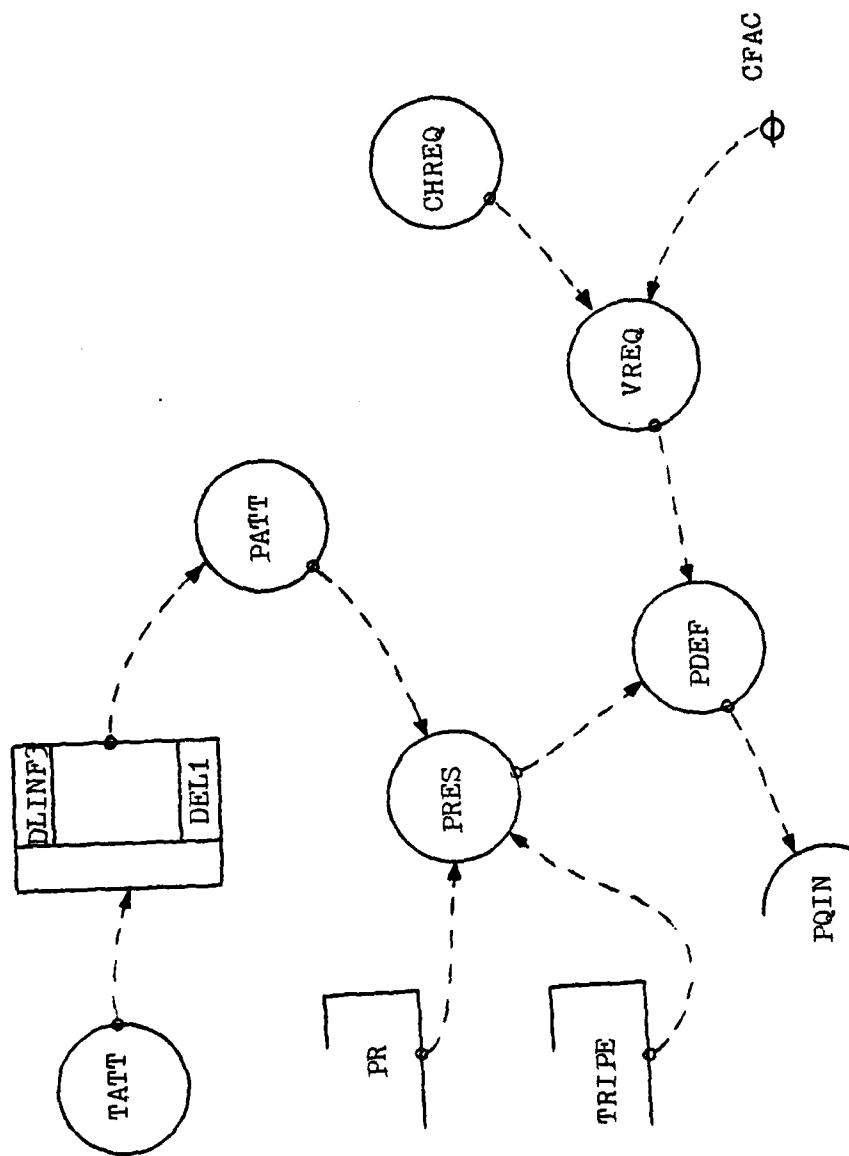


Figure 5-6. Projected Five Year Deficit.

attritions are in fact based on historical data and are calculated as a simple moving average of the past five years actual attrition values. The attrition values (PATT) for the various grades have been modeled as a two and one half year delay in applying current rates of attrition (TATT). The projected deficit sector equations are presented below:

PROJECTED DEFICIT IN 5 YEARS

```
PDEF.K(1,E)=0
PDEF.K(2,E)=MAX(CFAC*VREQ.K(2,E)-PRES.K(1,E)
-PRES.K(2,E),0)
PDEF.K(GP,E)=MAX(CFAC*VREQ.K(GP,E)-PRES.K(GP,E),0)
CFAC=1.6
VREQ.K(G,E)=IREQ(G,E)*CHREQ.K(G,E)
CHREQ.K(G,E)=1+STEP(CHS,CHT)
CHS=0/CHT=0
IREQ(*,1)=0/60/248/119/87
AVREQ.K(E)=SUMV(VREQ.K(*,E),1,GRADES)
AAVREQ.K=SUM(AVREQ.K)
PRES.K(G,E)=TR.K(G,E)+TPIPE.K(G,E)+SPIPE.K(G,E)
-PATT.K(G,E)
PRES(G,E)=TR(G,E)+TPIPE(G,E)-PATT(G,E)
PATT.K(G,E)=20*PTATT.K(G)*TR.K(G,E)
PTATT.K(G)=DLINF3(TATT.K(G),DEL1)
DEL1=10
```

Projected Inputs, Authorized Quota, Selection Sector

The projected five year deficit as calculated by HQ USAF is monitored on a quarterly basis although only one of these projections is used each year as the basis for seeking congressional funding approval. The current HQ USAF policy is to attempt to make up the total deficit in three years. Thus the total five-year deficit is divided into three equal annual inputs. This process is represented in Figure 5-7 by dividing the projected deficit (PDEF) by three to obtain the

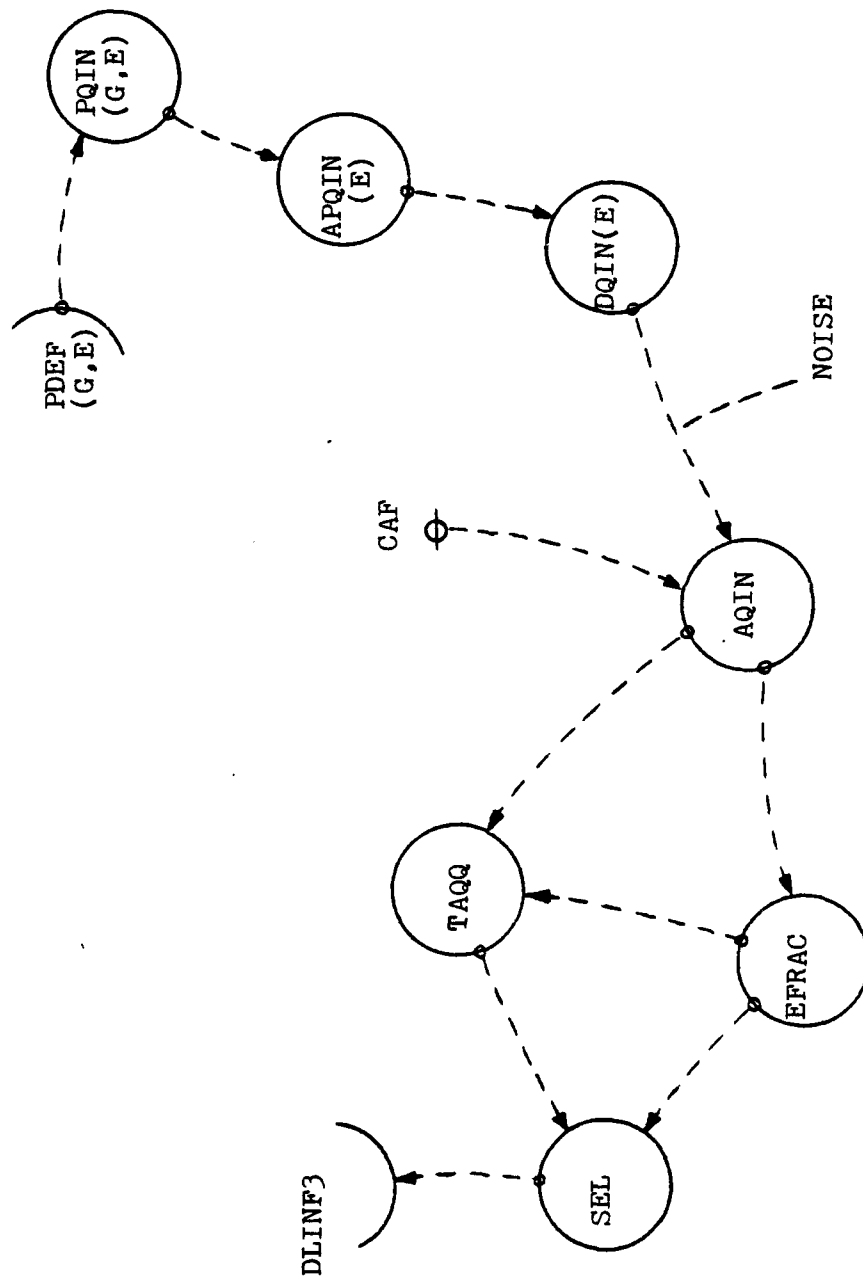


Figure 5-7. Projected Inputs, Authorized Quota, Selections.

annual inputs and further dividing by four to represent the projected quarterly inputs (by grade and ASC). Even though the projected quarterly input is categorized by grade and ASC, this information is filtered, and subsequent decisions are made on the basis of ASC considerations only. That is to say, grade is not considered.

The aggregate projected quarterly inputs (APQIN) are based on the projected deficit, however, they are subject to random, special requests from functional areas. These special requests for AAD slots has the effect of redistributing the projected inputs. The effect of these special requests has been represented in the flow diagram as noise, however, the net overall effect upon each ASC has been assumed to balance out in the long term. That is the value given to these variations is zero. The mathematical equations show aggregate inputs equaling desired inputs (DQIN).

The desired quarterly inputs are then converted to authorized quarterly inputs through the application of a congressional approval factor (CAF). The congressional approval factor represents the proportion of the desired inputs requested by the Air Force that are approved by Congress. Throughout the seventies the CAF has declined from a value of one, where Congress approved all desired inputs, to a current value of about one half, where Congress is approving only about fifty percent of the desired inputs.

The resulting total authorized quota (TAQQ) is then broken down into the proportion each ASC represents of the total authorized quota. The numbers of each ASC authorized then forms the basis for the selection process.

The selection process has been modeled as a set of decision rules which accounts for ASC requirements and available resources by grade. The major difficulty in the selection process is to obtain sufficient numbers of first lieutenants and junior captains. It is claimed by managers in the Graduate Education system that education of eligible officers in these two grades provides the maximum benefit to the Air Force because of two primary reasons. First, these officers are sufficiently mature and have had some experience of already working in, and having some knowledge of the Air Force systems and procedures. The second reason is that the Air Force expects to retain these officers for a lengthy period and consequently receive a pay back in terms of work performed.

The most recent data for the years 1978-80 indicates that captains constitute about twenty three percent and first lieutenants about sixteen percent of the total inputs up to a maximum of twelve and nineteen per annum. The balance of sixty one percent is made up predominately of second lieutenants with a small number of majors in the proportions ninety five percent and five percent respectively. There have historically been no selections of lieutenant colonels

even though they constitute a part of the total inventory of AAD holders. The equations for this sector are shown below.

PROJECTED QTLY INPUTS

$PQIN.K(G,E) = PDEF.K(G,E)/12$
 $APQIN.K(E) = SUMV(PQIN.K(*,E), 1, GRADES)$

DESIRED QTLY INPUTS

$DQIN.K(E) = APQIN.K(E) * (1 + NOIF * NOISE())$
 $NOIF = 0$

AUTHORISED QTLY QUOTA

$AQQ.K(E) = CAF * DQIN.K(E)$
 $CAF = 1$
 $TAQQ.K = SUM(AQQ.K)$

QTLY SELECTION OF STUDENTS

$SEL.K(1,E) = EFRAC.K(E) * (MAX((TAQQ.K - 7.75) * .95, 0))$
 $SEL.K(2,E) = EFRAC.K(E) * (MIN(TAQQ.K * .4, 3.10))$
 $SEL.K(3,E) = EFRAC.K(E) * (MIN(TAQQ.K * .6, 4.65))$
 $SEL.K(4,E) = EFRAC.K(E) * (MAX((TAQQ.K - 7.75) * .05, 0))$
 $SEL.K(5,E) = 0$
 $EFRAC.K(E) = AQQ.K(E) / TAQQ.K$

The model has been constructed in such a way as to allow for consideration of both validated requirements and resources by both ASC and grade. The model was initially limited to all ASC's of the electrical engineering discipline, however, the core memory limits of the computer used by the CREATE system could not handle the 14 ASC's by 5 grade matrix for both resources and requirements. Consequently, the model was limited to the 4IYY Academic Specialty Code across all grades for both requirements and resources.

Table 5-1 shows a complete summary of parameter values and data employed in developing the DYNAMO computer

TABLE 5-1

Model Building Data

<u>SYMBOL</u>	<u>PARAMETER</u>	<u>VALUE</u>	<u>SOURCE</u>
TING	Time in grade 01-05	6/8/32/16/0	MPC
TPIPE	Initial pipeline resource	66/19/28/7/0	AFIT
CFAC	Coverage factor		USAF HQ
FAIL	School attrition rate	0.009	AFIT
TATT(1)	Attrition grade 01	0.0195	MPC
(2)	Attrition grade 02	0.0195	MPC
(3)	Attrition grade 03	0.0195	MPC
(4)	Attrition grade 04	0.008	MPC
(5)	Attrition grade 05	0.023	MPC
PRCOL	Colonel promotion rate	0.0348	MPC
IREQ	Current validated requirements	0/60/248/119/87	AFIT
SEL	Grade selection proportions	See Description	AFIT/MPC

NOTE: All values are expressed in quantities per quarter, with the exception of IREQ

equations as well as the respective sources. Appendix C contains the complete set of computer equations for the model. The computer equations were reconfirmed against the flow diagram and then to the causal loop diagram as a means of model verification.

This chapter contains a description of the development of the mathematic model from data obtained during the research process. In order to examine the behavior of the AADMS (as represented by the model) to various system and policy changes it was necessary to conduct sensitivity analysis of the model. The sensitivity analysis procedure and results are described in Chapter 6.

Chapter 6

VALIDATION AND ANALYSIS OF THE MODEL

Introduction

Presented in this chapter are a discussion of model validity and the results of model testing. The tests that were made on the model involved making two types of changes: parameter changes and policy changes. It is stressed that the model, in its present form, can only be applied to one Academic Specialty Code (ASC) at a time, although it was originally designed to handle groups of ASCs having similar parameters, through the use of arrays. Difficulties were experienced with computer memory requirements for the original version of the model (capable of handling up to fourteen ASCs simultaneously) and therefore testing was carried out using one ASC only. The ASC selected was 4IYY, Electrical Engineering, which has a relatively large number of validated billets (a total of 514). The initial phase of confirming the acceptability of the model was through the model validation process.

Validation of the Model

A model should only be created for a specific purpose, and its adequacy or validity evaluated only in terms of that purpose. . . . The concept of validation should be considered one of degree and not one of an either-or notion; it is not a binary decision variable where the model is valid or invalid [16:208].

The above approach to validation of simulation models is widely accepted by those in the field of dynamic modeling (8:115-129; 6:181-184). As discussed in Chapter 3, it was the approach adopted in this research effort.

The primary emphasis of the validation process was aimed at developing the model such that the selection of system boundaries, and the inclusion of system variables and structure, would provide a model valid for its intended purpose - to provide a vehicle for testing alternate policies and structure for improving the achievement of the system's goals. Thus, the validation process was concerned primarily with internal validity and was an integral part of the model development. That is to say, validation involved reviewing the model at each stage of development, using all available information, to ensure that essential system structure, variables, and parameters were adequately represented. The adequacy required was subjectively determined, based upon overall knowledge of the system and the objectives of the research.

Another aspect of model validation involved verifying the equations against the flow diagrams to ensure that the translation from pictorial form to mathematical form was accurate.

With regard to external validity (the ability of the model to replicate real world behavior), the paucity of past data and the parameter changes that have occurred over

recent years, precluded an objective evaluation of validity by a comparison of model input-output with real system input-output. Nevertheless, model runs were carried out and the behavior of the model was plausible and not inconsistent with the generally understood behavior of the system.

The next section of this chapter addresses the approach taken in sensitivity analysis of the model.

Sensitivity Analysis

Sensitivity analysis was conducted on selected parameters internal and external to the system to determine the response of the model's output to such changes. The sensitivity of system behavior to such changes in parameters is important because it indicates the degree to which the system should attempt to control the parameter and/or the extent to which system policies and/or structure should be altered to reduce the sensitivity. From the model point of view, sensitivity analysis indicates the degree of accuracy with which the parameters need to be measured if the model is to be adequate for its intended purpose.

Sensitivity analysis results presented in this section are relevant only for the 4IYY ASC, and may not be valid for other ASCs where the overall number and grade distribution of validated requirements may be considerably different. A computer run using a hypothetical ASC having a different grade distribution from the 4IYY distribution confirmed that grade distribution can significantly alter the model output.

The finding is significant in highlighting one of the reasons why the coverage ratio may appear acceptable in an aggregate sense but is not so when the coverage ratio is required to consider the respective grade distributions of both the resources and the requirements. In order to examine coverage ratios for other than the 4IYY ASC the only amendment to the model is to include current resources, validated billets, and current levels in the educational pipeline as applicable to the selected ASC.

The basic version of the model, with the corresponding parameters and policies, was established through the model building process. Some parameters, such as time in grade and course length, were considered to be sufficiently stable over time as to justify their exclusion from the analysis.

As indicated previously, the output selected for sensitivity analysis was the coverage ratio of resources to validated requirements by grade. The Air Force is currently using a coverage ratio of 1.6. In the subsequent analysis of the output of the model, coverage ratios below 1.6 have been considered unacceptably low and coverage ratios in excess of 1.8 have been considered an excessive education of resources. To determine the sensitivity of the coverage ratio to each parameter change, only one parameter was changed from the basic configuration for each run.

Changes to Policies

Most system dynamics models have an objective of enabling policy changes and/or structural changes to be tested for their effect on overall system performance. The objective of testing the effect of policy changes with the AADMS model was not to arrive at specific recommendations concerning changes to the current system. Rather, the aim was to provide a better understanding of system behavior, and to show how the model can be used to assist AADMS managers to test the responses and outputs of the system to a variety of policy changes.

Some of the system policies are partly implicit. For example, the policies used to select officers to undergo graduate education are normally influenced to a large degree by the availability of eligible officers. Thus, policy changes may be only partly controllable. In these circumstances, the decision maker may wish to test the impact of the changing, but limited, policies which can be adopted.

Three types of policy changes were considered when analyzing the sensitivity of the model. The first of these policy changes involved changing the grade distribution of selectees to undergo graduate education. As previously stated, this policy is not entirely discretionary, but is usually strongly influenced by the grade distribution of the available officers. The second policy to be changed was the coverage factor, which is supposedly set to provide

sufficient resources to man all validated billets. The third policy to be changed was the time period over which the projected five-year shortfall would be made up. The response of the model to both the parameter changes and the policy changes (shown in Table 6-1) are discussed in greater detail in the following sections of this chapter.

Congressional Approval Factor

All of the sensitivity analysis computer runs of the model were based on the assumption that the Air Force would request, and Congress would approve, funds for graduate education based on the resource requirements indicated by the quota setting policies. Thus, in building the model and in subsequent sensitivity analysis, the Congressional approval factor was given the value of 1.0 and treated as an exogenous variable. Considering the Congressional approval factor in this way enabled sensitivity analysis of parameters which are inherent in the system and policy changes which are under the direct control of the Air Force. The current situation is, however, because of Congress' dissatisfaction with the Air Force's management of the AADMS, the value for the Congressional approval factor is approximately 0.5. That is, Congress is approving approximately half the Air Force's required inputs to meet the projected deficit. Figures D-7 and D-7A resulting from run 7, demonstrate the response curve trends over time for the aggregate coverage ratio

(ACRAT) and the coverage ratio by grade (CRAT) respectively, given the starting conditions of resources equal to objectives. The results show that the aggregate coverage declines to nominally 1.1 and that coverage by grade ranges from a best value of 1.5 for lieutenant colonel down to values of about 1.0 for captains and majors. The implication of this finding is that the projected deficit will never be made up.

Attrition Rate Changes

As shown in Table 6-1 attrition was increased by one percent (run 2) and five percent (run 3) per year over and above the basic rates of attrition currently existing, and described in Chapter 4. The aggregate coverage ratio (ACRAT) which includes all grades commences at 1.6 (Figure D-2) and steadily drops to approximately 1.44 after 32 quarters and then increases to approximately 1.49 after 80 quarters. By applying progressively increasing rates of attrition as represented on runs 1 through 3 it was found that the magnitude and shape of the aggregate coverage ratio response curve did not change significantly as is evident from an examination of Figures D-1, D-2 and D-3.

In contrast the coverage ratios (CRAT) which show coverage by grade, demonstrated greater divergence from the basic response curves as the attrition fractions increased. The main impact in the grade structure was on the 02. and 05 grades where, with increasing attrition, the 05 grade

TABLE 6-1

Model Computer Runs

PARAMETER CHANGES

RUN N ^o	CAF	CFAC	ACON	DEL1	CHS	OBSFAC	SELECTION/QUARTER				
							01	02	03	04	05
1	1.0	1.6	0	10	0	0	BASIC*				
2	1.0	1.6	.0025	10	0	0					
3	1.0	1.6	.0125	10	0	0					
4	1.0	1.6	.0125	2	0	0					
5	1.0	1.6	0	10	+0.2	0					
6	1.0	1.6	0	10	-0.2	0					
7	0.5	1.6	0	10	0	0					

POLICY CHANGES

8	1.0	1.6	0	10	0	0	.3	.4	.2	.1	0
9	1.0	1.6	0	10	0	0	.4	.4	.1	.1	0
10	1.0	1.6	0	10	0	0	.3	.3	.3	.1	0
11	1.0	1.6	0	10	0	0	.3	.6	.3	.1	0
12	1.0	1.6	0	10	0	0	.4	.5	.1	0	0
13	1.0	2.0	0	10	0	0	BASIC				
14	1.0	1.6	0	9 ⁺	0	0	BASIC				
15	1.0	1.6	0	16 ⁺	0	0	BASIC				
16	1.0	1.6	0	10	0	.02	BASIC				

NOTE * BASIC SELECTION: 02 = 3.1/QTR + make-up delay
 03 = 4.65/QTR
 01 = 95% of balance
 04 = 5% of balance

coverage ratio fell to 1.4 and the 02 grade coverage ratio rose to a value in excess of 2.8. This is to be expected with higher rates of attrition since, based on the current decision rule for selection, and a 100 percent Congressional authorization, most of the additional shortages due to the increased attrition are made up by selection of second lieutenants.

The basic model run (run 1, Figure D-1A) showed that the coverage ratios for captains and majors fell from a starting condition of 1.6 to a final value of nominally 1.3 after a run of 80 quarters. These values changed marginally, but not significantly, as attrition increased (Figures D-2A and D-3A). The inference drawn from this result is that with high rates of attrition leading to high inputs of second lieutenants, promotions into the grades of captain and major, as well as education of those grades are able to counter the attrition.

Attrition Information Delay

The delay in applying attrition information (DEL1) was reduced from the 10 quarters to only 2 quarters. Runs 3 and 4, including the 10 and 2 quarter delays respectively, showed only marginal differences in shape and magnitude of their response curves for both aggregate coverage ratio and coverage ratio. The response curves are shown in Figures D-3, D-3A, D-4 and D-4A.

This finding should not be viewed in isolation since although the reduction of the information delay concerning attrition did not appear to be a factor, the actual magnitude of the attrition change was demonstrated above to be highly significant. Consequently, delays in applying different attrition rates are of considerable importance. A comparison of the outputs of runs 1 and 4 (Figures D-1, D-1A and D-4, D-4A respectively) demonstrates the continually lagging and lower coverage ratios for the delayed application of the higher attrition rates.

Validated Requirements Change

A step increase of 20 percent and a step decrease of 20 percent were applied to the existing number of validated requirements, 16 quarters after commencement of the runs. The response curves for runs 5 and 6, representing a 20 percent increase and 20 percent decrease in requirements respectively, are shown in Figures D-5, D-5A and D-6, D-6A respectively.

The 20 percent increase in requirements caused the aggregate coverage ratio value, which was already declining, to drop sharply to nominally 1.25, followed by a recovery back towards the desired value of 1.6. An examination of Figure D-5A reveals that the coverage ratio by grade suffered a step drop when the increase in requirements occurred, however, these coverage ratios all recovered to the same

steady state position as for the basic model (runs) by the end of the run period (80 quarters).

A similar situation, but reversed, occurred with the application of a 20 percent decrease in validated requirements. When the step decrease in requirements was applied, the aggregate coverage ratio jumped to 1.9 and then commenced a decline to approximately 1.4 before bottoming and commencing to track the 1.6 required value. As with the case of the requirements increase, the coverage ratios by grade returned to the same steady state conditions as the basic model by the end of the run period.

A similarity exists between the runs involving attrition changes and those involving changes to validated requirements in that, given the current selection policy, short falls and overages in the aggregate coverage are dealt with by selecting more or fewer second lieutenants, regardless of what individual grade coverage ratios are being achieved. As indicated by the response curves of Figure D-6A, the disparities between respective grade coverage ratios fluctuate dramatically and for at least 70 quarters before achieving a steady state condition. Once the steady state condition is achieved the grade coverage ratios are not the desired 1.6 value. The nominal value for grades lieutenant through lieutenant colonel were 1.9, 1.4, 1.3, and 1.9.

Obsolescence

Obsolescence of all forms of education is of growing concern; however, no allowance is currently made by the Air Force for this factor. An obsolescence factor (OBSFAC) has been included in this model to test the long term effects such a factor has in eroding the effective pool of AAD holder resources. Figures D-16 and D-16A show the model output for the aggregate coverage ratio and grade coverage ratio respectively. The rate of obsolescence is clearly dependent upon a number of factors such as the applicability of subsequent work function to the education and the frequency of update courses relevant to the original education. Obsolescence does not necessarily result in a complete loss of the resource, since losses from highly specialized fields of endeavor may be considered a gain into a more generalized field but where an advanced degree is still required. Figures D-16 and D-16A show the coverage ratios for run 16 (Table 6-1) using an arbitrarily selected obsolescence rate of 0.02 of the total resources per quarter (8 percent per year). The aggregate coverage ratio falls from a starting value of 1.6 to a final steady state value of 1.25. The coverage ratio by grade (Figure D-16A) demonstrates the exceedingly poor coverage for the grades of captain, major and lieutenant colonel. As with all other sensitivity analysis performed on the model, whenever the aggregate coverage ratio falls significantly, the coverage ratio for second

lieutenants increases rapidly in an attempt to meet the low coverage ratios for the other grades. In this case the coverage ratios for second lieutenants is approximately 2.4 and does not exceed 1.2 for the other grades. Under the present selection policies, the greater the deficit, the greater the input of second lieutenants into the advanced academic training pipeline, thus the model representation of Figure D-16A is not unexpected.

The previous sections have presented an examination of the responses of the model output to the parameter changes of attrition, attrition information delay, Congressional approval factor, obsolescence and validated requirements. The parameter changes proved not to significantly vary the aggregate coverage ratios but did significantly affect the coverage ratio by grade. The following sections address the effects and implications of policy changes on the coverage ratios in the aggregate and by grade.

Policy Changes

Three types of policy changes were considered when analyzing the sensitivity of the model. The first of these changes involved changing the proportions of the grade selected for AAD selection, the second involved changing the 1.6 coverage factor and the third involved changing the desired time period over which the five year window projected shortfalls would be made up.

Selection Changes. A variety of grade selection policies were chosen and the computer model was run to determine the effect of these policies on both the aggregate and grade coverage ratios. Table 6-1 shows the selection policies adopted and the results of runs 8-12 are shown in Figures D-8 through D-12A. It is evident from these response curves that the selection policies affect both the aggregated and grade coverage ratios. Improvements in certain grades could be achieved but only at the expense of other grades. With the model of the existing system, it proved impossible through selection policies to achieve a 1.6 coverage ratio for captains and majors. It was, however, possible to achieve this ratio for lieutenants and lieutenant colonels simultaneously under the same selection policy.

Coverage Factor Change. A change in the current coverage factor value of 1.6 to an increased value of 2 resulted in improved coverage ratios for all grades. The coverage ratios for the model run (run 13) of this policy change is shown in Figures D-13 and D-13A. Under this policy, all grades are able to achieve at least a 1.6 coverage ratio; with lieutenants and lieutenant colonels about 2.4 and captains and majors slightly in excess of 1.6. A slightly more equitable distribution of coverage ratio between the grades was obtained by adjusting the selection policies, however, the results were not substantially different from those presented in Figures D-13 and D-13A.

It is of course recognized that increasing the aggregate coverage factor to 2.0 will require increased numbers of selections of officers for graduate education, as well as Congressional approval for those numbers.

Rate of Deficit Make-up

As discussed in Chapter 4, the projected five-year deficit is divided into three annual quotas (12 quarters) to make up that deficit. Figures D-14, D-14A and D-15, D-15A show the response curves for make-up periods of 9 and 16 quarters respectively, in lieu of the current make-up period of 12 quarters. The more rapid make-up period of 9 quarters for the deficit produced marginally improved grade coverage ratios over the current policy. By increasing the make-up period, however, a substantial delay was built into the system, which resulted in substantial declines in all grade coverage ratios such that the values for lieutenant and lieutenant colonel achieved steady state values of 1.6 and for majors and captains the final value was 1.2

The discussions in this chapter have related to the sensitivity of the model's output of coverage factor in the aggregate and by grade, to changes of system parameters and Air Force policies. The results of the findings have been discussed progressively throughout the chapter. Chapter 7 discusses the implications of these findings and the conclusions derived therefrom.

Chapter 7

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

The objective of this research was to develop an understanding of the behavior of the Air Force Advanced Academic Degree Management System (AADMS), and to reflect this understanding in the form of a computerized model. The specific objectives relevant to this research were:

1. Identify the structure of the Air Force graduate education system.
2. Identify the interrelationships between the components of the system.
3. Describe the flow patterns which exist between the components of the system.
4. Construct a mathematical model which represents the components, interrelationships, and flow patterns of the system.
5. Portray this logic in a computerized model.
6. Validate the model to demonstrate that it adequately replicates the Air Force graduate education system structure and decision making process.
7. Identify areas of sensitivity or critical areas in Air Force graduate education management policy.

The purpose of this chapter is to provide a summary of the research effort relative to the above objectives, to present conclusions derived from the research, and to propose recommendations.

Research Summary

The identification and description of the system structure, and interrelationships between components, was accomplished in the initial development of the model. This initial conceptual model was based on information gained from a review of pertinent literature and interviews with personnel involved with the system. The resulting conceptual model was presented in the form of causal loop diagrams for each of the subsystems identified. The formulation of system dynamics flow diagrams achieved the third objective of describing the flow patterns existing within the system, and identified the decision functions and parameters involved. The flow diagrams also served to define those system elements to be included in the mathematical model. The fourth and fifth objectives were realized through the formulation of a mathematical model written in the DYNAMO computer language. The mathematical model was verified by comparing the DYNAMO equations with the flow diagrams to ensure that the mathematical model accurately reflected the relationships. Validation of the model involved progressively ensuring that the model adequately replicated the real system, using the best available information, as well as running the model to verify that output was not contrary to expected system output. The identification of sensitive or critical areas involved conclusions drawn from both research into the system

and analysis conducted using the mathematical model. These conclusions are presented in the next section.

Conclusions

The following conclusions were made as a result of research into the AADMS during development of the conceptual model:

1. The AADMS is based upon highly subjective information resulting from supervisors' perceptions of two highly complex areas - job requirements (skills and knowledge), and the sources of those skills and knowledge. Also, the leniency of the official criteria allows individual and situational factors to enter the decision process at each level.
2. Congressional attitude towards the Services' graduate education programs is currently a major factor in the performance of the AADMS. Congressional pressure is exerted on the system in three ways. First, Congress directly authorizes the funding necessary to facilitate full-time, fully-funded graduate education in the Air Force. Second, Congress has acted to control the total number of validated billets. Third, Congress is concerned that the AFIT resident schools achieve a high utilization rate.
3. Annual quotas determined by HQ USAF are specified in terms of ASC and academic level only, whereas the projected resource shortfall needs to be made up by officers specified in terms of AFSC, grade, ASC, and academic level.
4. The level of officers who are eligible and available to undergo graduate education is currently acting to constrain AFMPC's ability to select students. Even at the current rate of graduate education inputs, which is low relative to the projected shortfalls, the proportion of second lieutenants is higher than AFMPC would prefer.
5. The setting of quotas in the face of fiscal and manpower availability constraints is not based on a formal, systematic procedure for identifying which of AAD shortfall billets have relative priority. Rather, it is based on pressure to utilize AFIT, requests for HQ USAF functional managers and a "preference" for scientific and technical ASCs.

6. The objectives of AFMPC with regard to the management of AADMS resources are clearly subservient to other manpower management and career development objectives, and the only definitive policy is that graduates of fully-funded programs must be assigned to a validated billet as soon as practicable after schooling, but not later than their second tour after completion. Apart from this requirement, the subsequent utilization objectives of AAD resources relative to other manpower objectives is unclear. Therefore, Congress cannot be assured that the expensively obtained AAD resources will be effectively utilized - it all depends on other manpower objectives.

The following conclusions were made as a result of sensitivity analysis of the computer model.

The development of the model enabled system responses to be evaluated in the light of various parameter and policy changes. The computer run of the basic model, as well as all subsequent runs involving parameter changes, resulted in aggregate coverage ratios less than the Air Force's objective of 1.6. Analysis of the coverage ratio by grade, for those computer runs involving parameter changes, demonstrated widely varying values across the grades of lieutenant through to lieutenant colonel. A significant result from this analysis, however, that notwithstanding which parameter changes were made, the coverage ratios for the grades of captain and major were insensitive to the parameter changes and remained at a nominal value of 1.3. Parameter changes did, however, produce considerable changes in the coverage ratios for the grades of second lieutenant and lieutenant colonel. The sensitivity of the coverage ratios of these latter two grades to parameter changes has important ramifications for the Air Force to both predict when such changes might occur,

and to develop a system which will cater for the results of such changes. As discussed in Chapter 6, even though changes in attrition rates and validated requirements produced significant changes in the coverage ratios by grade; the most significant changes of the coverage ratios occurred when the obsolescence factor was introduced into the model. In its current projection of the five-year deficit, the Air Force considers only the likely attrition of AAD holders. This research indicates that, when considering coverage ratios by grade, obsolescence and changes of requirements may be equally as significant as attrition.

Changes to selection policies were influential in achieving changes to the grade coverage ratios, however, no selection policy analyzed via the model was effective in raising all the grade coverage ratios to the Air Force's desired level of 1.6. Under the range of selection policies modeled, no policy could achieve more than two grades with coverage ratios equal to or in excess of 1.6.

The only policy change attempted during the course of this research which produced a model output coverage ratio of at least 1.6 for every grade was to increase the coverage factor from 1.6 to 2.0. The implications of this policy would require the Air Force to educate 25 percent more officers than current numbers as indicated by the current projection deficit and consequent make-up figures.

The primary objective of building the model was to provide AADMS managers with an insight into the structure of the system and an understanding of how the system reacts to parameter and policy changes. The system dynamics computer model was run using the electrical engineering Academic Specialty Code (ASC) 4IYY. The use of this ASC in the computer model was designed to be illustrative of the power of the model's ability to reflect the results of parameter changes and policy decisions in terms of the systems behavior and the systems output. The conclusions stated throughout this research, must of necessity, apply directly to the AADMS in terms of the 4IYY Academic Specialty Code, however, the research and corresponding model development and analysis has highlighted important parameters and system decision structure which is applicable to all Academic Specialty Codes.

Recommendations

The major recommendation resulting from this research is that the AADMS model should be used to experiment with various quota-setting and selection policies/decision rules, to determine which policies, in combination, will provide the required AAD resources (having the correct grade/ASD combinations) at the least cost. Expansion of the mathematical model to include the AFSC may also be desired, and this can be readily accomplished by the addition of an extra dimension to the appropriate model arrays.

The second recommendation is that the manning factor be logically established at a value (or values) such that if resource objectives (determined by the validated requirements and the manning factor) are attained, a high percentage of validated billets can be filled. The achievement of this recommendation requires that the relative priorities of the AADMS objectives and the other manpower management/career development objectives be more explicitly defined, and that other factors which affect the ability of MPC to fill validated billets be identified and considered. Without a realistically established manning factor, performance of the overall AADMS cannot be assessed.

The third recommendation is that the AADMS should, in all its processes and decision-making, account for and manage AAD requirements and resources on the bases of AFSC, grade, ASC, and academic level. This recommendation implies that quota setting should involve consideration of these four dimensions. Even if MPC is unable, due to insufficient available/eligible officers, to meet the quota requirements, it would at least provide them with an objective. Continued inability to meet the more specific quota requirements should provide impetus to analysis of the problem and the initiation of corrective action.

The fourth recommendation pertains to the requirements determination process. Much has been written and spoken about the subjectivity of this process, both within

and outside the DOD. Despite consideration of this problem by the Air Force and the other Services, no alternative to the current billet validation approach has yet gained DOD support. The recommendation is made that a review be made of current job analysis techniques to determine the practicality of establishing and maintaining a data base on all Air Force officer positions, and a complementary data base on education and training curricula. The job data base is envisioned as containing quantitative data on the knowledge and skills required of each job incumbent, and the other data base would contain data on the potential sources of the same categories of skills and knowledge. If this approach were shown to be feasible, a decision rule could be developed to establish AAD requirements. The decision rule would, necessarily, be subjective, but the approach could provide overall consistency in the determination of AAD requirements, and a means of assigning relative priorities to requirements - a necessary function to permit rational quota setting in times of fiscal and/or manpower constraints.

The remaining recommendations pertain to further research which needs to be conducted into the AADMS. First, research should be conducted into the problem of obsolescence of AADs in the Air Force. The rate at which skills and knowledge become obsolete appears to depend on such factors as the academic field, the extent to which the skills/knowledge are actually applied, the timing and duration of assignments

that are basically unrelated to the academic field, and the nature of the skills/knowledge (specific skills are likely to be harder to retain than, say, general approaches to problem solving). An improvement of knowledge in the field of skills/knowledge deterioration would be valuable to the AADMS for the formulation of rational policies to provide for the consideration and management of obsolescence.

Second, research should be conducted to determine which factors control the level of officers who are available and eligible for entry into full-time, fully-funded graduate education programs. Efficient operation of the AADMS requires that officers be available and eligible in sufficient numbers to permit selection of officers to be made at the appropriate grades. Officers available/eligible for selection constitute resources, and it is necessary that resource management be conducted to ensure that AAD requirements can be met. Until the factors which determine the level of available resources are identified, action to correct deficiencies (if taken) will not be based on adequate information.

APPENDICES

APPENDIX A
TERMINOLOGY

Academic Specialty Code (ASC) - A four character code which defines the academic field of study required, e.g., digital computers code is ØCDB. All AAD requirements are based on ASCs. AFM 300-4-II gives a full listing of codes (22:1-1).

Air Force Specialty - A group of positions that require common qualifications. Each AFS has a title and a code (21:1-1), e.g., metallurgist (title) and 2655 (Air Force Specialty Code). AFR 36-1, Officer Classification Regulation, contains the authorized AF Specialties and AF Specialty Codes (AFSCs) authorized for use.

Career Area - A grouping of utilization fields broadly related on the basis of required skills and knowledge (22:1-1), e.g., Logistics Career Area, Scientific and Development Engineering Career Area.

Functional Manager - An official at HQ USAF, major command, or a joint and unified activity, who is designated as responsible for the operation and administration of a career area (22:101), e.g., personnel, logistics.

Utilization Field - A group of Air Force Specialties (AFSs) that are related, based on required skills and knowledge (22:101), e.g., Pilot. AFR 36-1, Officer Classification Regulation, contains the authorized utilization fields.

APPENDIX B
PERSONAL INTERVIEWS

Major Gary E. Baugh, USAF
Chief of Graduate Education Programs
HQ USAF (MPPE)

Major Joseph W. Carl, USAF
Resident Degree Programs Branch
Educational Plans and Operations
Air Force Institute of Technology

Mr. John E. Gates,
Computer Specialist
Engineering Services and Personnel Systems Division
Air Force Data Services Center

Major Dan Gill, USAF
Resident Degree Programs Branch
Educational Plans and Operations
Air Force Institute of Technology

Mr. Richard H. Lee
Deputy Director of Admissions
Air Force Institute of Technology

Mr. Harold E. Lillie
Director of Admissions
Air Force Institute of Technology

Major Roscoe E. Moulthrop III.
Chief of AFIT Assignments
Career Management Branch
Directorate of Personnel Resources and Distribution
Air Force Manpower and Personnel Center

APPENDIX C
COMPUTER PROGRAM LISTING

0010* GRADUATE EDUCATION SYSTEM
 0020NOTE G=OFFICER GRADE STRUCTURE
 0030NOTE E= ACADEMIC SPECIALITY CODE
 0040C ASC=1
 0050C GRADES=5
 0060C GRADEL=4
 0070NOTE
 0080FOR E=1,ASC
 0090FOR G=1,GRADES
 0100FOR G0=1,GRADEL
 0110FOR G2=2,GRADES
 0120FOR GG=1,2
 0130FOR GP=3,5
 0140NOTE
 0150NOTE TOTAL RESOURCES BY GRADE AND ASC
 0160NOTE
 0170L $TR.K(G,E)=TR.J(G,E)+DT*(GAINS.JK(G,E)$
 0180X $-LOSSES.JK(G,E))$
 0190N $TR(G,E)=CFAC*VREQ(G,E)$
 0200A $ATR.K(E)=SUMV(TR.K(*,E),1,GRADES)$
 0210A $AATR.K=SUM(ATR.K)$
 0220A $CRAT.K(1,E)=0$
 0230A $CRAT.K(2,E)=(TR.K(1,E)+TR.K(2,E))/(VREQ.K(2,E)+.0001)$
 0240A $CRAT.K(GP,E)=TR.K(GP,E)/(VREQ.K(GP,E)+.0001)$
 0250A $ACRAT.K(E)=ATR.K(E)/(AVREQ.K(E)+.0001)$
 0260A $AACRAT.K=AATR.K/AAVREQ.K$
 0270NOTE TR=TOTAL RESOURCES
 0280NOTE VREQ=VALIDATED REQUIREMENTS
 0290NOTE ATR=ATTRITION
 0300NOTE CRAT=COVERAGE RATIO BY GRADE & ASC
 0310NOTE ACRATE=AGG COVERAGE RATIO BY ASC
 0320NOTE AACRAT=AGG COVERAGE RATIO
 0330NOTE CFAC=COVERAGE FACTOR
 0340NOTE
 0350NOTE RESOURCE LOSSES
 0360NOTE
 0370R $LOSSES.KL(G0,E)=ATT.K(G0,E)+PR.K(G0+1,E)+OBS.K(G0,E)$
 0380R $LOSSES.KL(GRADES,E)=ATT.K(GRADES,E)+PRCOL.K(E)+OBS.K(GRADES,E)$
 0390A $OBS.K(G,E)=TR.K(G,E)*OBSFAC$
 0400C $OBSFAC=.02$
 0410A $ATT.K(G,E)=TR.K(G,E)*TATT.K(G)$
 0420A $TATT.K(1)=.0195*ARCF.K$
 0430A $TATT.K(2)=.0195*ARCF.K$
 0440A $TATT.K(3)=.0195*ARCF.K$
 0450A $TATT.K(4)=.008*ARCF.K$
 0460A $TATT.K(5)=.023*ARCF.K$
 0470A $ARCF.K=1+ACON*TIME.K$
 0480C $ACON=0$

0490A PR.K(1,E)=0
 0500A PR.K(G2,E)=(TR.K(G2-1,E)-ATT.K(G2-1,E))/
 0510X TING(G2-1)
 0520T TING(*)=6/8/32/16
 0530A PRCDL.K(E)=(TR.K(GRADES,E)-ATT.K(GRADES,E))*0.0348
 0540NOTE OBS=OBSOLENCE
 0550NOTE TATT=ATTRITION TABLE
 0560NOTE ACON=ATTRITION INC/TIME
 0570NOTE PR=PROMOTION RATE
 0580NOTE TING=TIME IN GRADE
 0590NOTE ARCF=ATTRITION RATE FRACTION
 0600NOTE
 0610NOTE RESOURCE GAINS
 0620NOTE
 0630R GAINS.KL(G,E)=GRAD.K(G,E)+PR.K(G,E)
 0640NOTE GRAD=GRADUATION RATE
 0650NOTE
 0660NOTE EDUCATION PIPELINE FLOW
 0670NOTE
 0680A GRAD.K(G,E)=(TPIPE.K(G,E))/6
 0690NOTE TPIPE=EDUC PIPELINE TOTAL
 0700NOTE
 0710NOTE EDUCATION PIPELINE LEVEL
 0720NOTE
 0730L TPIPE.K(G,E)=TPIPE.J(G,E)+DT*(PGAIN.JK(G,E)
 0740X -PLOSS.JK(G,E))
 0750N TPIPE(G,E)=TPIPI(G,E)
 0760T TPIPI(*,1)=40/31/40/7/0
 0770R PGAIN.KL(G,E)=DELAYP(SEL.K(G,E),DEL2,SPIPE.K(G,E))
 0780X +PPR.K(G,E)
 0790C DEL2=2.5
 0800R PLOSS.KL(G0,E)=PLATT.K(G0,E)+GRAD.K(G0,E)+PPR.K(G0+1,E)
 0810R PLOSS.KL(GRADES,E)=PLATT.K(GRADES,E)+GRAD.K(GRADES,E)
 0820A PLATT.K(G,E)=(TPIPE.K(G,E)-GRAD.K(G,E))*FAIL
 0830C FAIL=.009
 0840A PPR.K(1,E)=0
 0850A PPR.K(2,E)=(TPIPE.K(1,E)-PLATT.K(1,E)
 0860X -GRAD.K(1,E))/TING(1)
 0870A PPR.K(3,E)=(TPIPE.K(2,E)-PLATT.K(2,E)
 0880X -GRAD.K(2,E))/TING(2)
 0890A PPR.K(4,E)=0
 0900A PPR.K(5,E)=0
 0910NOTE TPIPI=INITIAL PIPELINE
 0920NOTE PPR=PIPELINE PROMOTION RATE
 0930NOTE PLATT=PIPELINE ATTRITION RATE
 0940NOTE FAIL=PIPELINE DROP-OUT FACTOR
 0950NOTE DEL2=SELECTION DELAY
 0960NOTE

```

0970NOTE      PROJECTED DEFICIT IN 5 YEARS
0980NOTE
0990A      PDEF.K(1,E)=0
1000A      PDEF.K(2,E)=MAX(CFAC*VREQ.K(2,E)-PRES.K(1,E)
1010X      -PRES.K(2,E),0)
1020A      PDEF.K(GP,E)=MAX(CFAC*VREQ.K(GP,E)-PRES.K(GP,E),0)
1030C      CFAC=1.6
1040A      VREQ.K(G,E)=IREQ(G,E)*CHREQ.K(G,E)
1050A      CHREQ.K(G,E)=1+STEP(CHS,CHT)
1060C      CHS=0/CHT=0
1070T      IREQ(*,1)=0/60/248/119/87
1080A      AVREQ.K(E)=SUMV(VREQ.K(*,E),1,GRADES)
1090A      AAVREQ.K=SUM(AVREQ.K)
1100A      PRES.K(G,E)=TR.K(G,E)+TPIPE.K(G,E)+SPIPE.K(G,E)
1110X      -PATT.K(G,E)
1120NOTE      PDEF=PROJECTED DEFICIT
1130N      PRES(G,E)=TR(G,E)+TPIPE(G,E)-PATT(G,E)
1140A      PATT.K(G,E)=20*PTATT.K(G)*TR.K(G,E)
1150A      PTATT.K(G)=DLINF3(TATT.K(G),DEL1)
1160C      DEL1=10
1170NOTE      CFAC=COVERAGE FACTOR
1180NOTE      PDEF=PROJECTED DEFICIT
1190NOTE      PRES=PROJECTED RESOURCE
1200NOTE      IREQ=INITIAL REQUIREMENTS
1210NOTE      CHREQ=CHANGE IN REQUIREMENTS
1220NOTE      AVREQ=AGG REQUIREMENT BY GRADE
1230NOTE      AAVREQ=AGG REQUIREMENT
1240NOTE      SPIPE=CURRENT PIPELINE
1250NOTE      DEL1=ATTRITION INFO DELAY
1260NOTE
1270NOTE      PROJECTED QTLY INPUTS
1280NOTE
1290A      PQIN.K(G,E)=PDEF.K(G,E)/12
1300A      APQIN.K(E)=SUMV(PQIN.K(*,E),1,GRADES)
1310NOTE      PQIN=PROJECTED QTLY INPUT
1320NOTE      APQIN=PROJECTED QTLY INPUT BY GRADE
1330NOTE
1340NOTE      DESIRED QTLY INPUTS
1350NOTE
1360A      DQIN.K(E)=APQIN.K(E)*(1+NOIF*NOISE())
1370C      NOIF=0
1380NOTE      DQIN=DESIRED QTLY INPUT
1390NOTE      NOIF=RANDOM REQUIREMENTS
1400NOTE

```

```

1410NOTE      AUTHORISED QTLY QUOTA
1420NOTE
1430A      AQQ.K(E)=CAF*DQIN.K(E)
1440C      CAF=1
1450A      TAQQ.K=SUM(AQQ.K)
1460NOTE      AQQ=AUTHORIZED QTLY QUOTA BY ASC
1470NOTE      TAQQ=TOTAL AUTHORIZED QTLY QUOTA
1480NOTE      CAF=CONGRESSIONAL APPROVAL FACTOR
1490NOTE
1500NOTE      QTLY SELECTION OF STUDENTS
1510NOTE
1520A      SEL.K(1,E)=EFRAC.K(E)*(MAX((TAQQ.K-7.75)*.95,0))
1530A      SEL.K(2,E)=EFRAC.K(E)*(MIN(TAQQ.K*.4,3.10))
1540A      SEL.K(3,E)=EFRAC.K(E)*(MIN(TAQQ.K*.6,4.65))
1550A      SEL.K(4,E)=EFRAC.K(E)*(MAX((TAQQ.K-7.75)*.05,0))
1560A      SEL.K(5,E)=0
1570A      EFRAC.K(E)=AQQ.K(E)/TAQQ.K
1580NOTE      SEL=SELECTION BY GRADE & ASC
1590NOTE      EFRAC=ASC PROPORTION OF TOTAL
1600NOTE
1610NOTE      PROGRAM RUN AND OUTPUT INSTRUCTIONS
1620NOTE
1630PLOT      ACRAT(1)
1640PLOT      CRAT(*,1)(.8,2.8)
1650SPEC      DT=.25/LENGTH=80/PRTPER=4/PLTPER=2
1660RUN

```

APPENDIX D
MODEL ANALYSIS RESPONSE CURVES

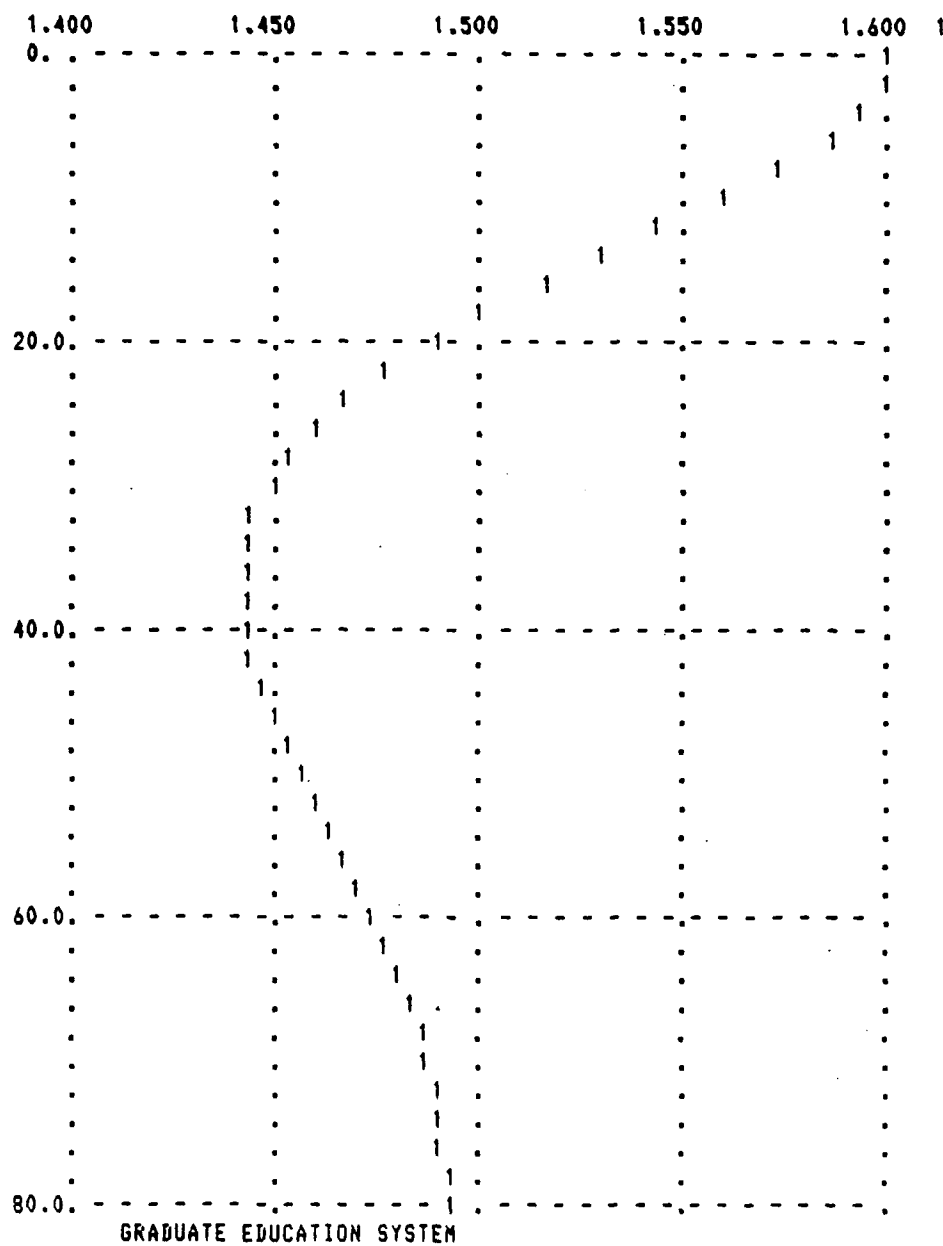


Figure D-1. Aggregate Coverage Ratio (RUN 1)

0.800	1.300	1.800	2.300	2.800	12345
0.	2	2			2345
.	23	5			34
.	2 34	5			
.	2 34	5			
.	2 3 4	5			
.	2 3 4	5			
.	2 3 4	5			
.	2 3 4	5			
.	23 4	5			
.	2 4	5			23
20.0	32-4		5		24
.	3 2		5		
.	3 42		5		
.	3 4 2		5		
.	3. 4 2		5		
.	3.4 2		5		
.	3.4 2		5		
.	34 2		5		
.	34 2		5		
40.0	3.	2	5		34
.	3.	2	5		34
.	3.	2	5		34
.	3.	2	5		34
.	3.	2	5		34
.	43	25			
.	43	25			
.	43	2			25
.	43	2			25
60.0	43	52			
.	4.3	52			
.	4.3	52			
.	4.3	52			
.	4.3	52			
.	4.3	2			25
.	4.3	2			25
.	4.3	2			25
.	4 3	2			25
.	4 3	25			
80.0	4-3	25			

GRADUATE EDUCATION SYSTEM

Figure D-1A. Coverage Ratio by Grade (RUN 1).

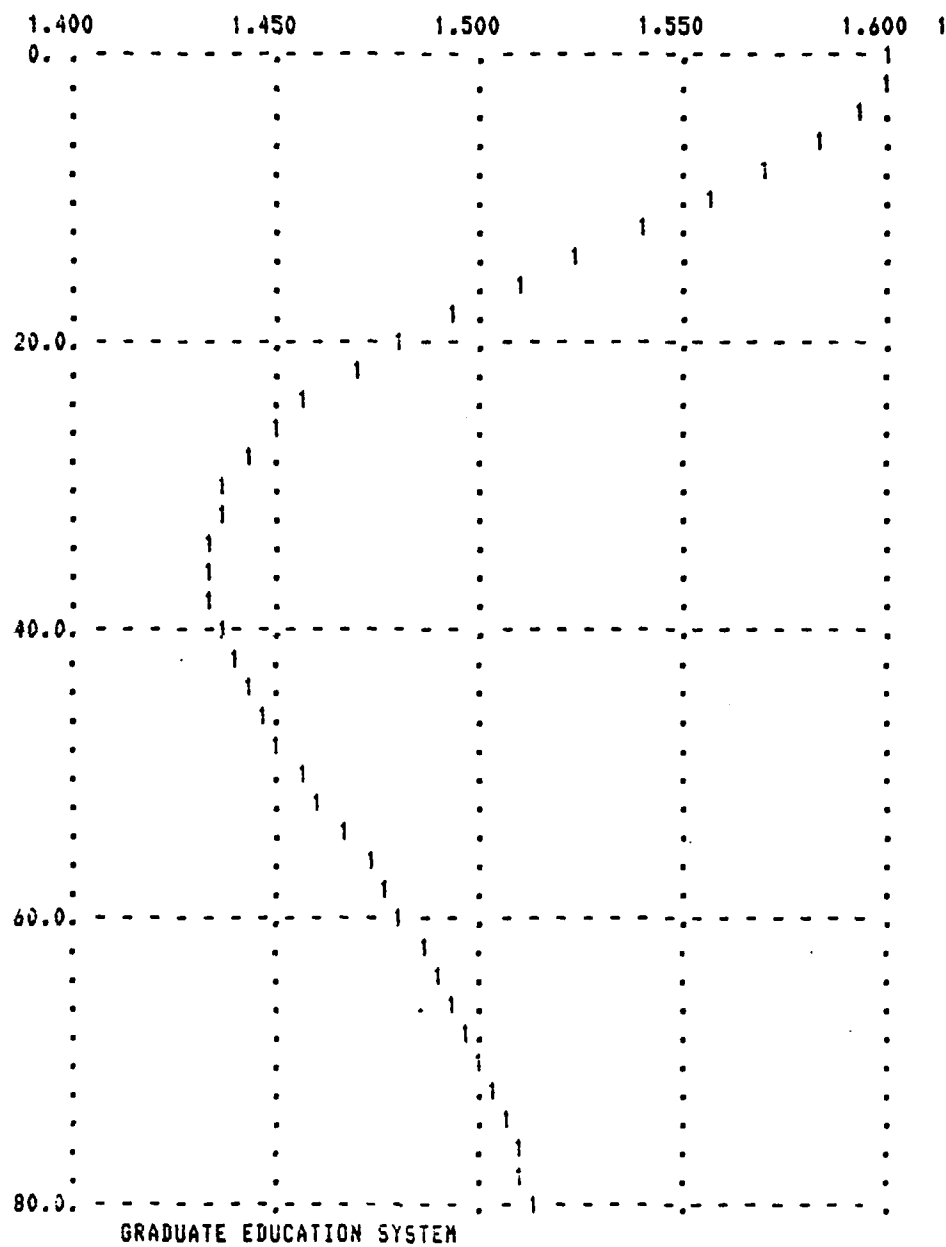


Figure D-2. Aggregate Coverage Ratio (RUN 2)

0.800	1.300	1.800	2.300	2.800	12345
0.	2	24 5			2345
.	.	2 34	5.	.	23
.	.	2 34	.5	.	.
.	.	2 3 4	.5	.	.
.	.	2 3 4	5	.	.
.	.	2 3 4	5	.	.
.	.	23 4	5	.	.
.	.	23 4	5	.	.
.	.	2 4	5	.	23
20.0	3 24	5	5	.	24
.	3 2	.	5	.	.
.	3 4 2	.	5	.	.
.	3. 4 2	.	5	.	.
.	3.4 2	.	5	.	.
.	3.4 2	.	5	.	.
.	3 4	2	5	.	.
.	3 4	2	5	.	.
.	34.	2.	5	.	.
.	34.	2	5	.	.
40.0	34.	2 5	.	.	.
.	34.	25	.	.	.
.	43.	52	.	.	.
.	43.	5 2	.	.	.
.	43.	5 2	.	.	.
.	43.	5 2	.	.	.
.	4 3	5 2	.	.	.
.	4 3	5 2	.	.	.
.	4 3	5 2	.	.	.
.	4 3	5 2	.	.	.
60.0	4. 3	5 2	.	.	.
.	4. 3	5 2	.	.	.
.	4.3	5 2	.	.	.
.	4.3	5 2	.	.	.
.	4.3	5 2	.	.	.
.	4. 3	5 2	.	.	.
.	4. 3	5. 2	.	.	.
.	4. 3	5. 2	.	.	.
.	4. 3	5. 2	.	.	.
80.0	4. 3	5. 2	.	.	.
.	4-3	5-2	.	.	.

GRADUATE EDUCATION SYSTEM

Figure D-2A. Coverage Ratio by Grade (RUN 2).

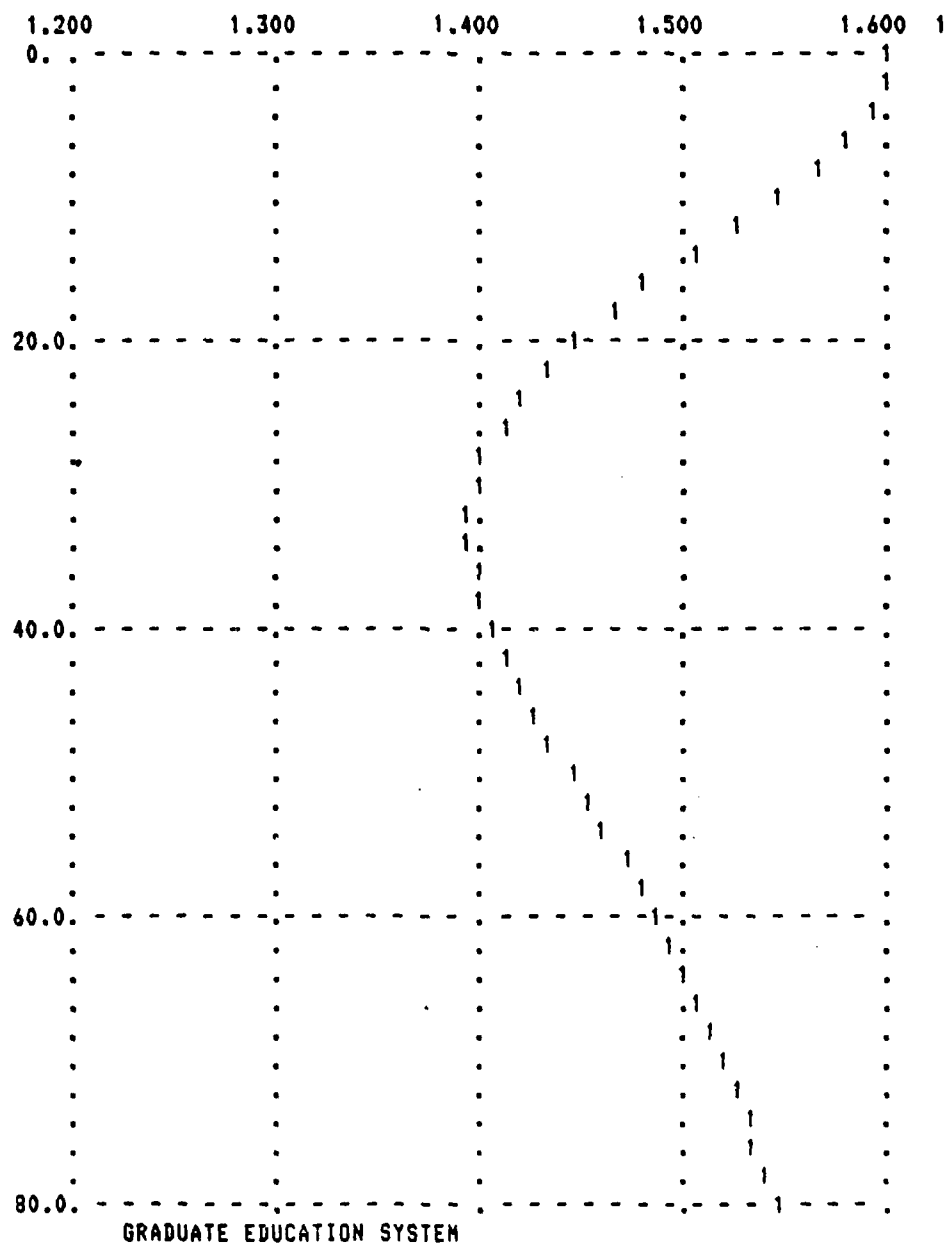


Figure D-3. Aggregate Coverage Ratio (RUN 3).

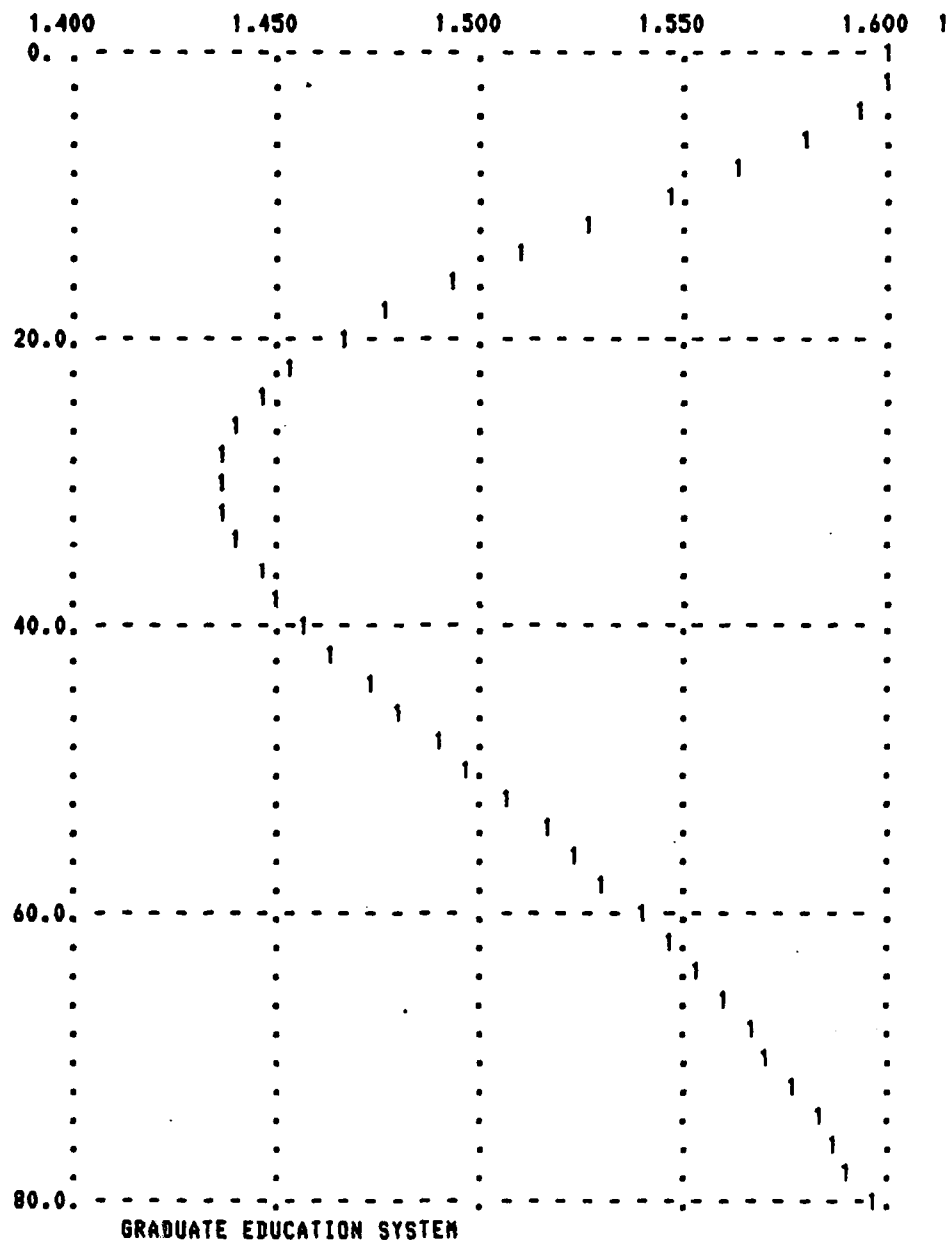


Figure D-4. Aggregate Coverage Ratio (RUN 4).

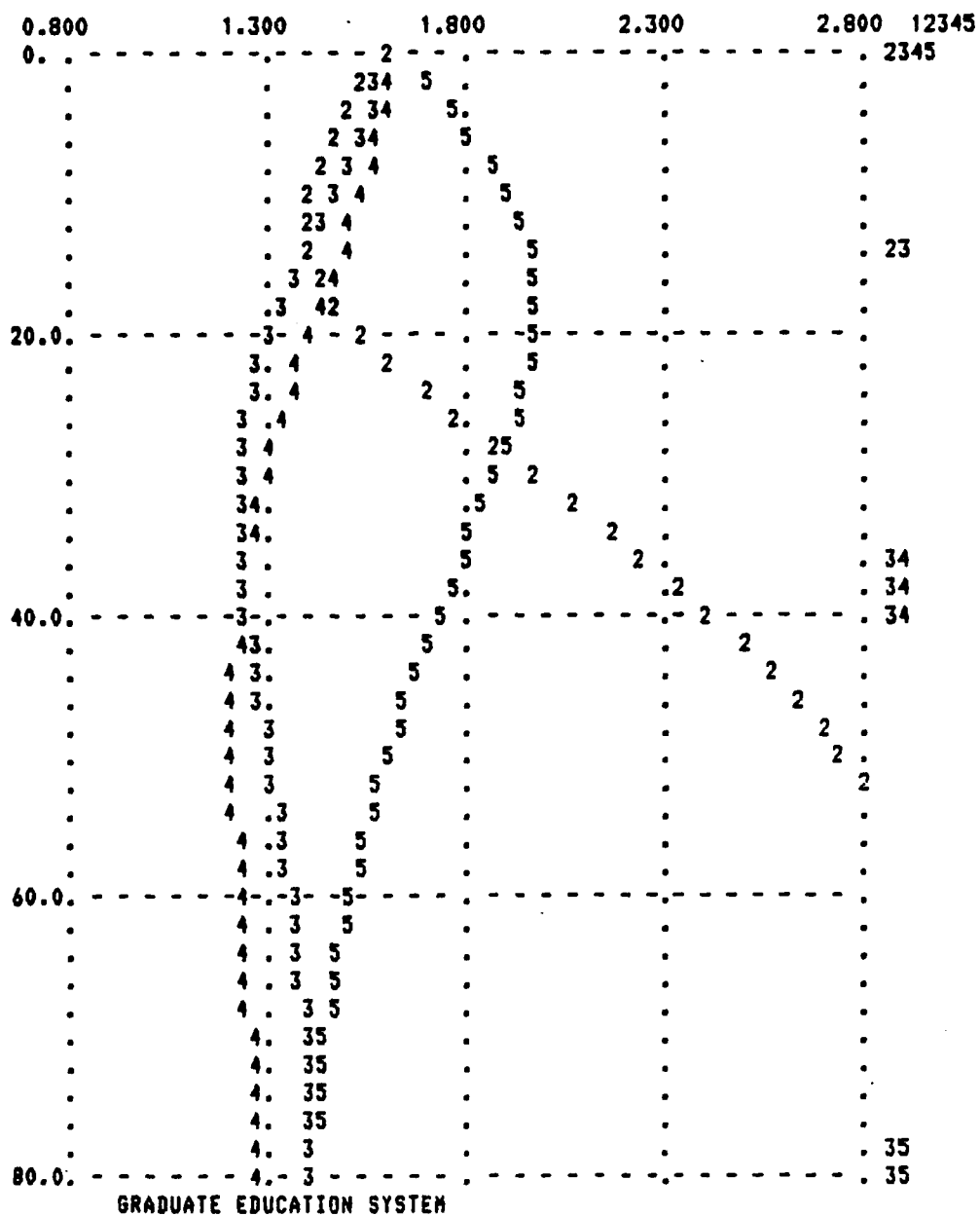


Figure D-4A. Coverage Ratio by Grade (RUN 4).

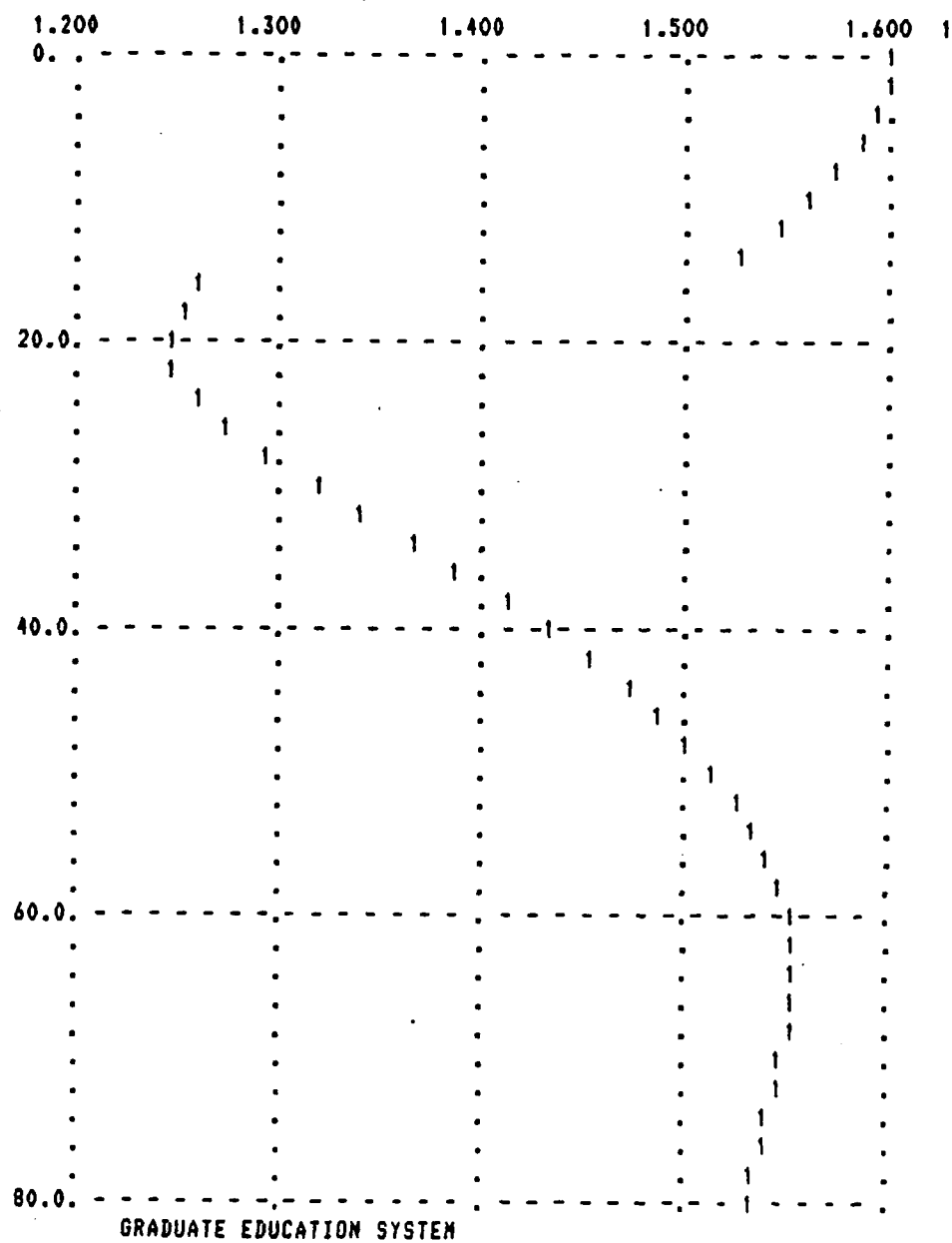


Figure D-5. Aggregate Coverage Ratio (RUN 5).

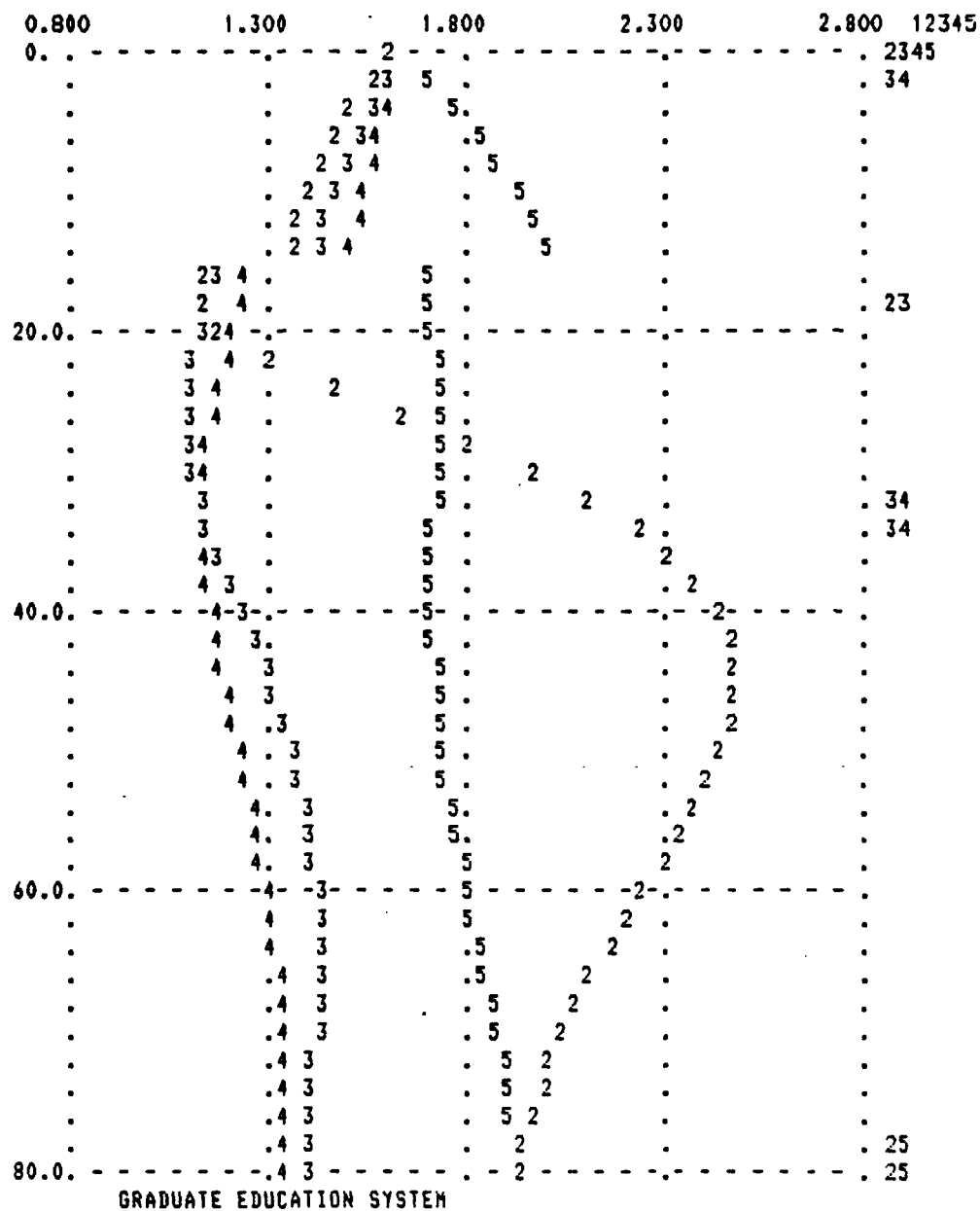


Figure D-5A. Coverage Ratio by Grade (RUN 5).

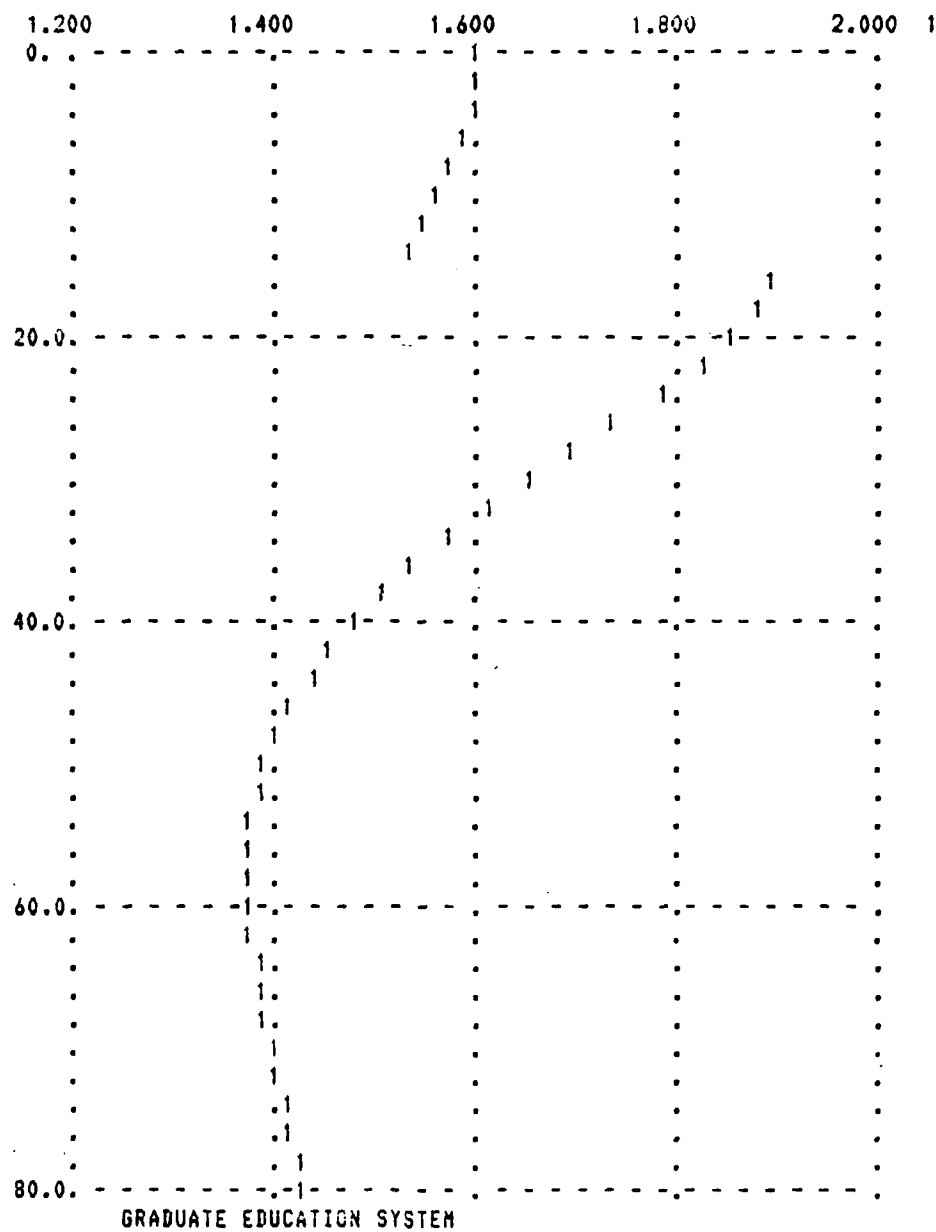


Figure D-6. Aggregate Coverage Ratio (RUN 6).

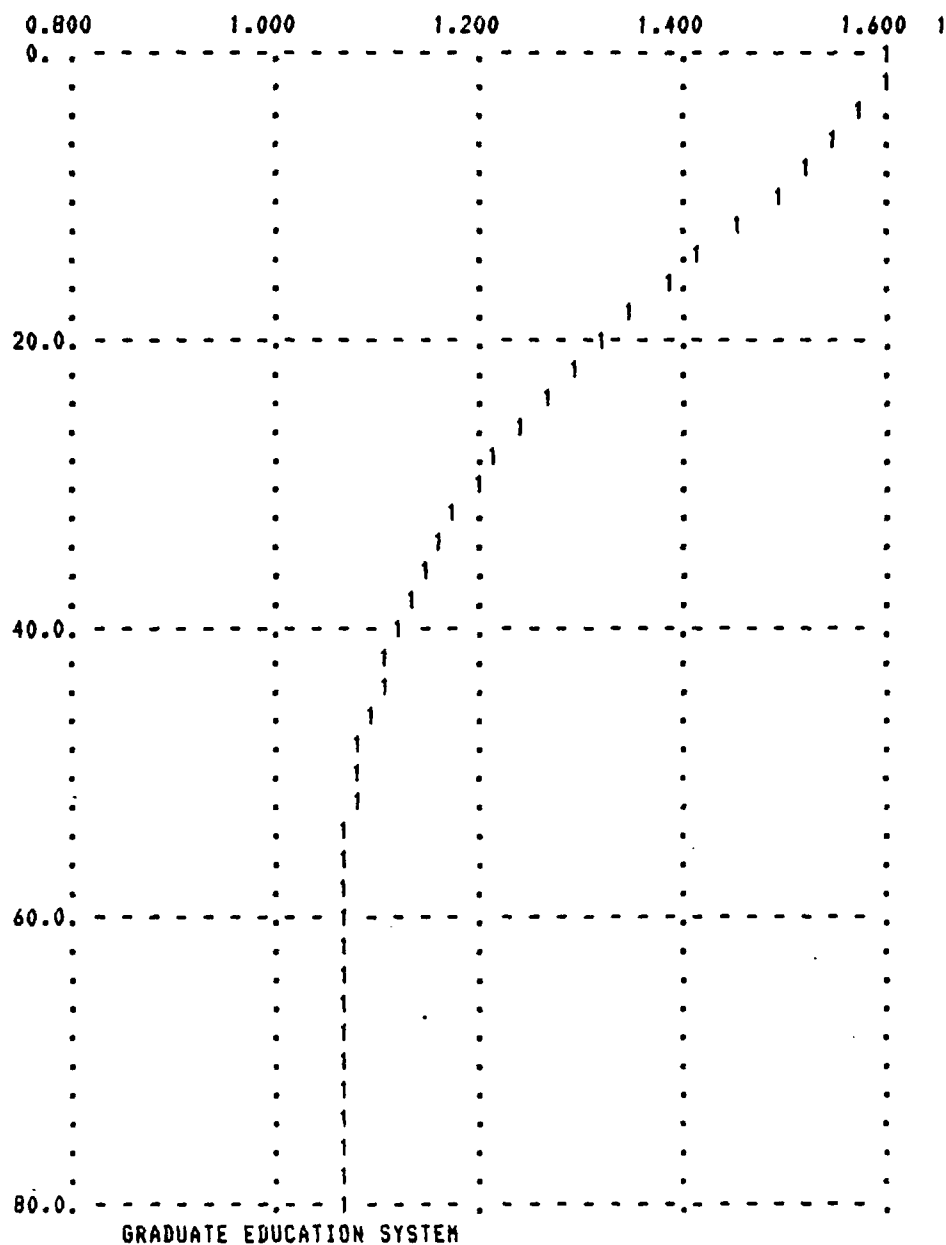


Figure D-7. Aggregate Coverage Ratio (RUN 7).

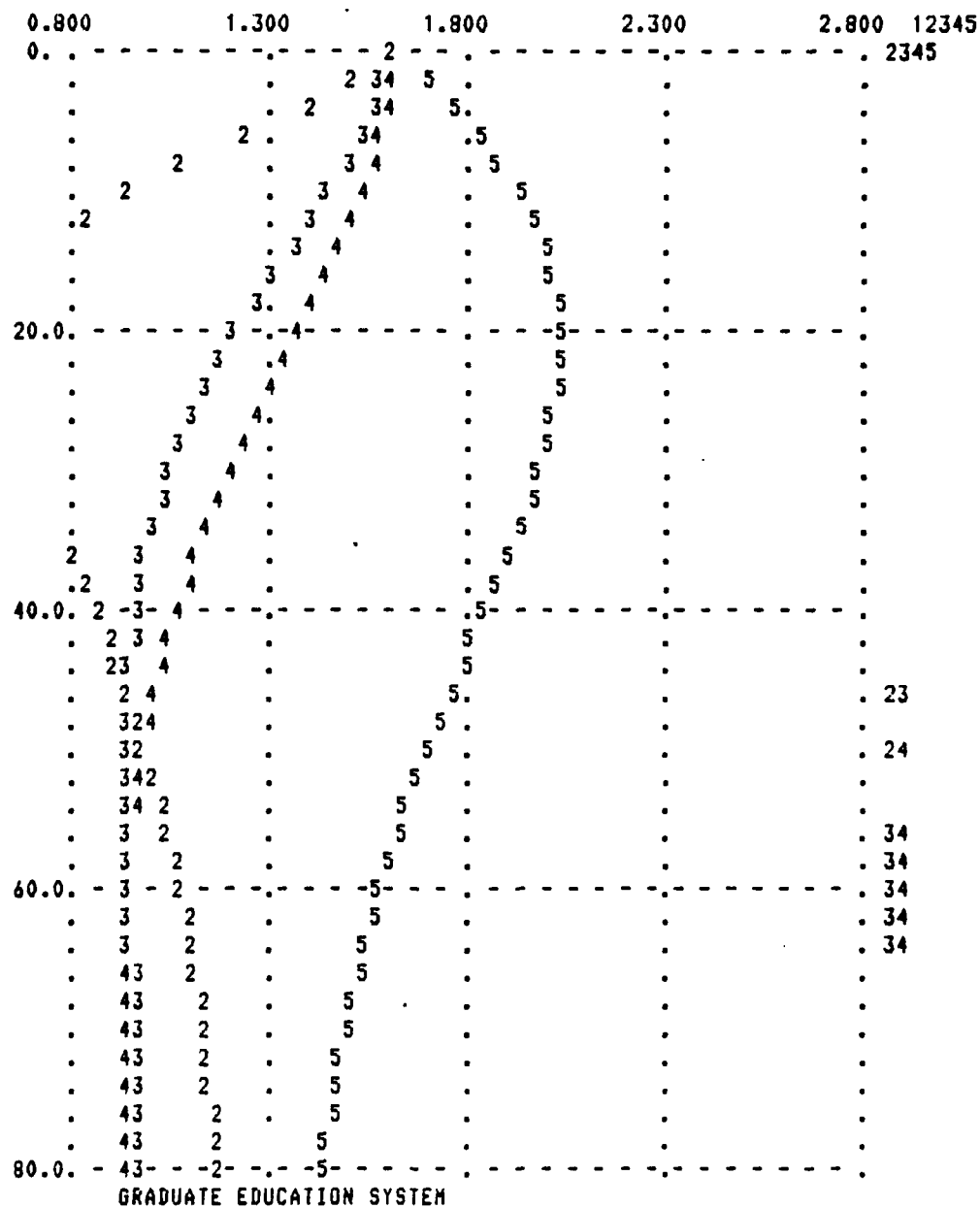


Figure D-7A. Coverage Ratio by Grade (RUN 7).

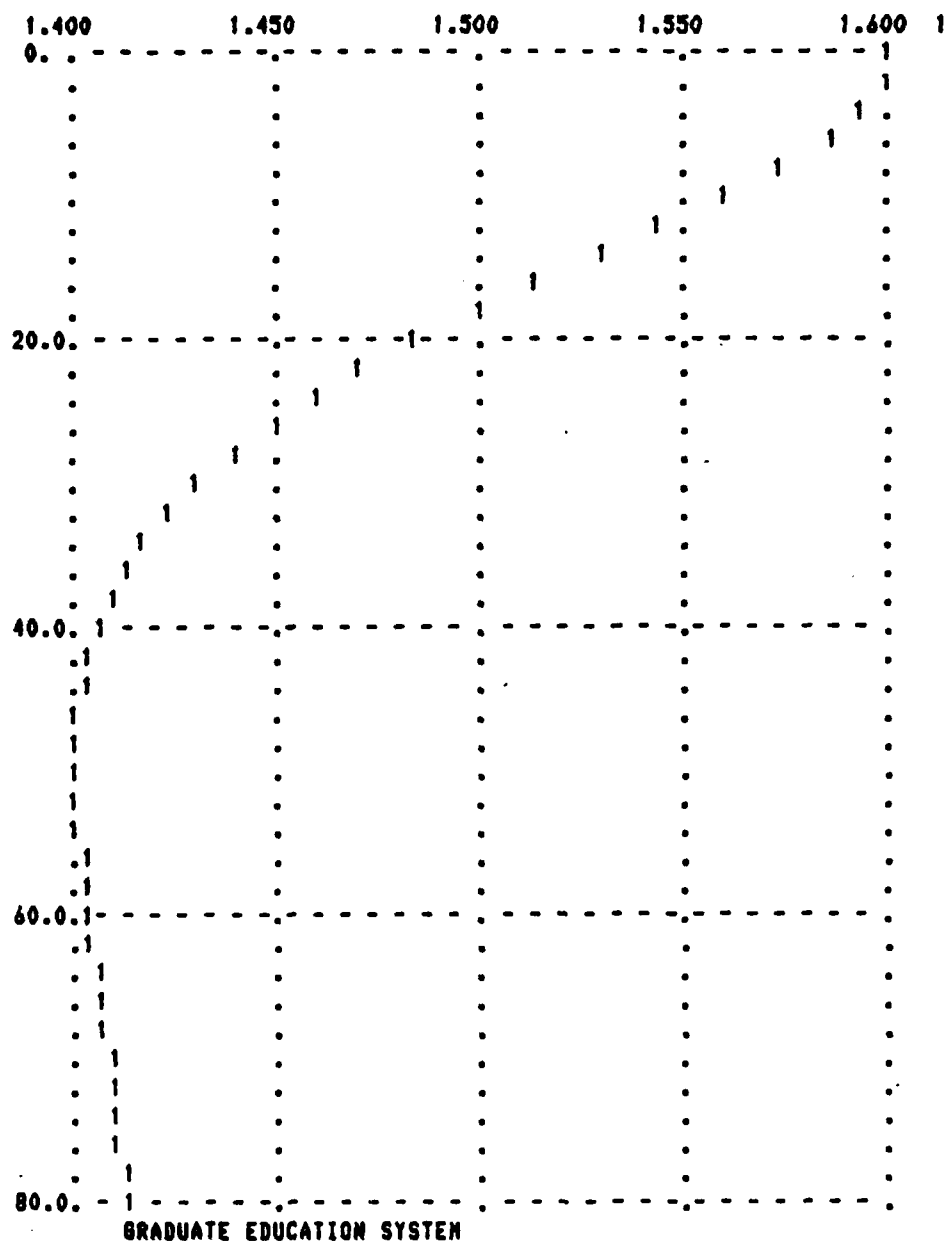


Figure D-8. Aggregate Coverage Ratio (RUN 8).

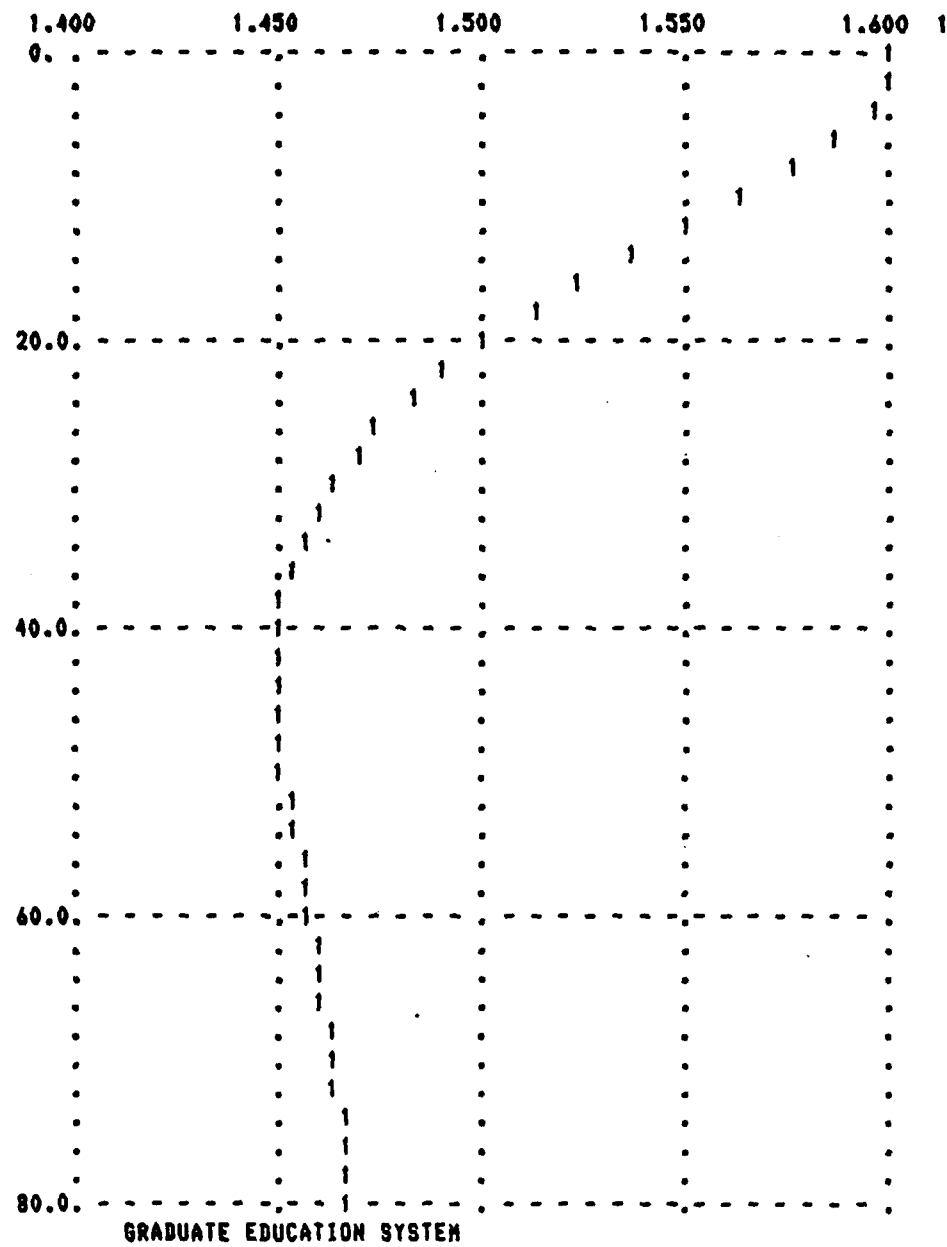


Figure D-9. Aggregate Coverage Ratio (RUN 9).

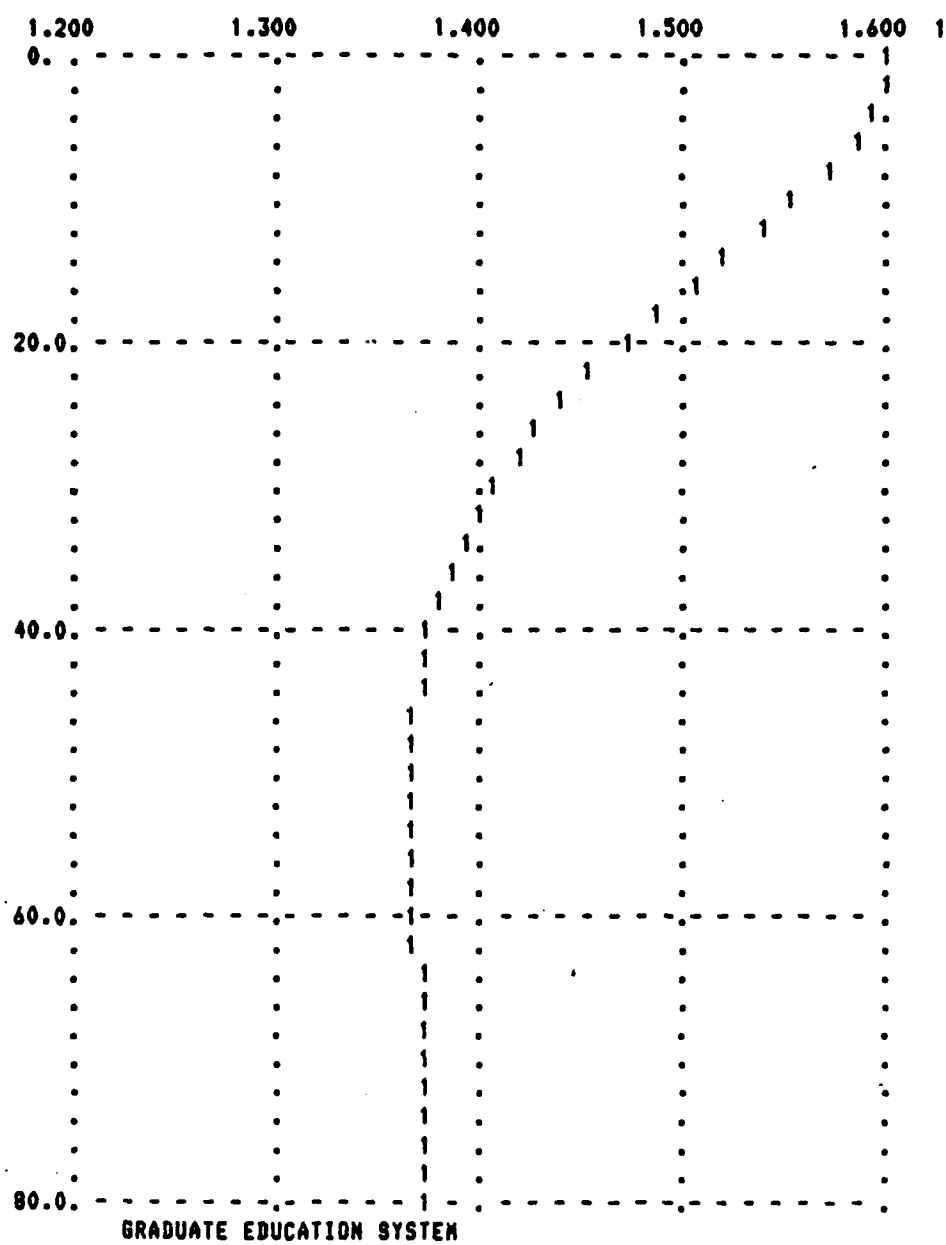


Figure D-10. Aggregate Coverage Ratio (RUN 10).

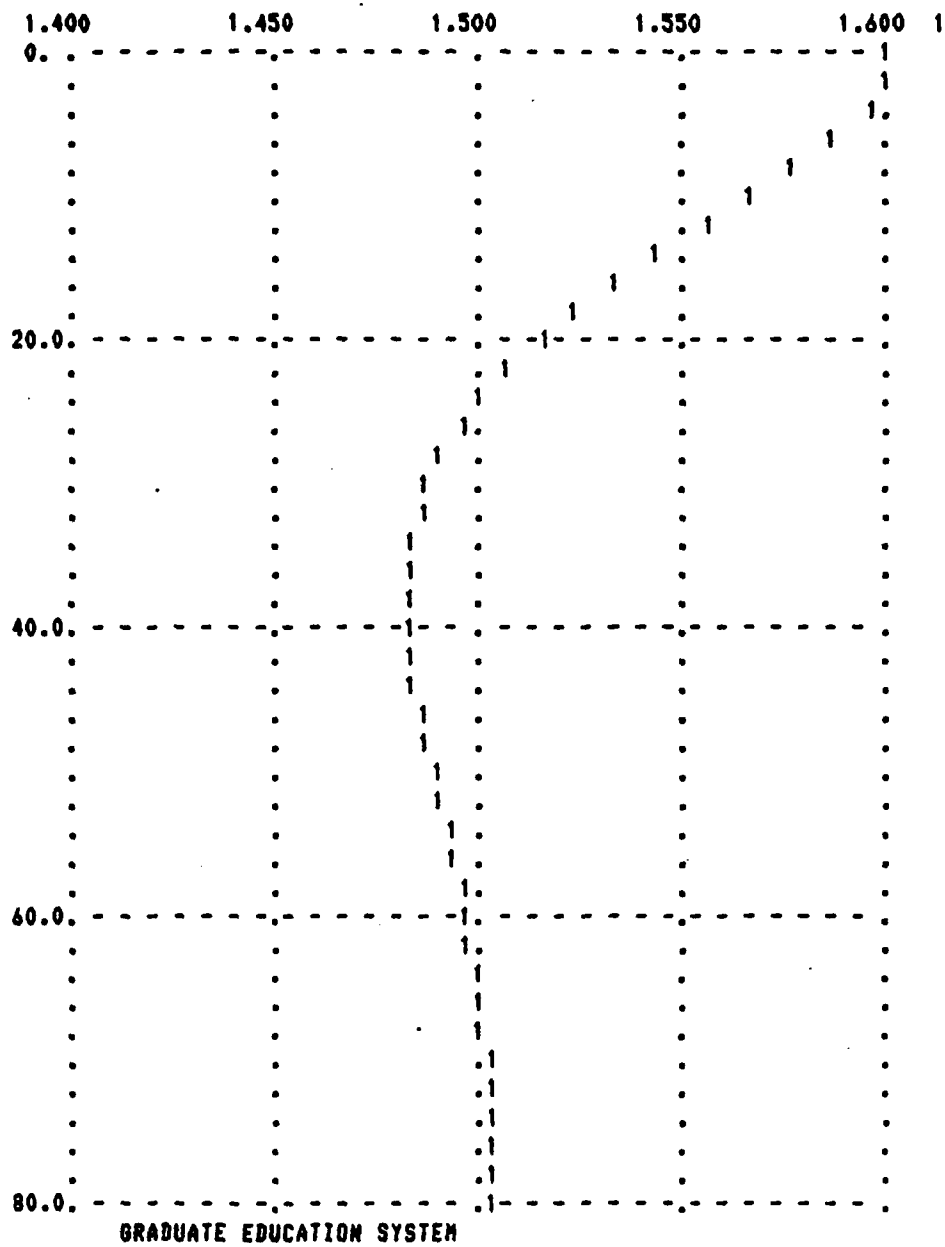
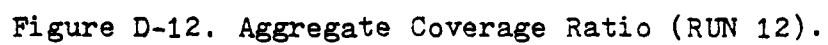


Figure D-11. Aggregate Coverage Ratio (RUN 11).

0.800	1.300	1.800	2.300	2.800	12345
0.0	2	5			2345
.	24	5			23
.	234	5			
.	24	5			23
.	324	5			
.	324	5			
.	3 2	5			24
.	342	5			
.	3 42	5			
.	34 2	5			
20.0	34	2	5		
.	34	2	5		
.	3	2	5		34
.	3	2	5		34
.	43	2	5		
.	3	2	5		34
.	43	2	5		
.	43	2	5		
.	4 3	2	5		
.	4 3	2	5		
40.0	4-3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
60.0	4-3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
80.0	4-3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
90.0	4-3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
.	4. 3	2	5		
GRADUATE EDUCATION SYSTEM					

Figure D-11A. Coverage Ratio by Grade (RUN 11).



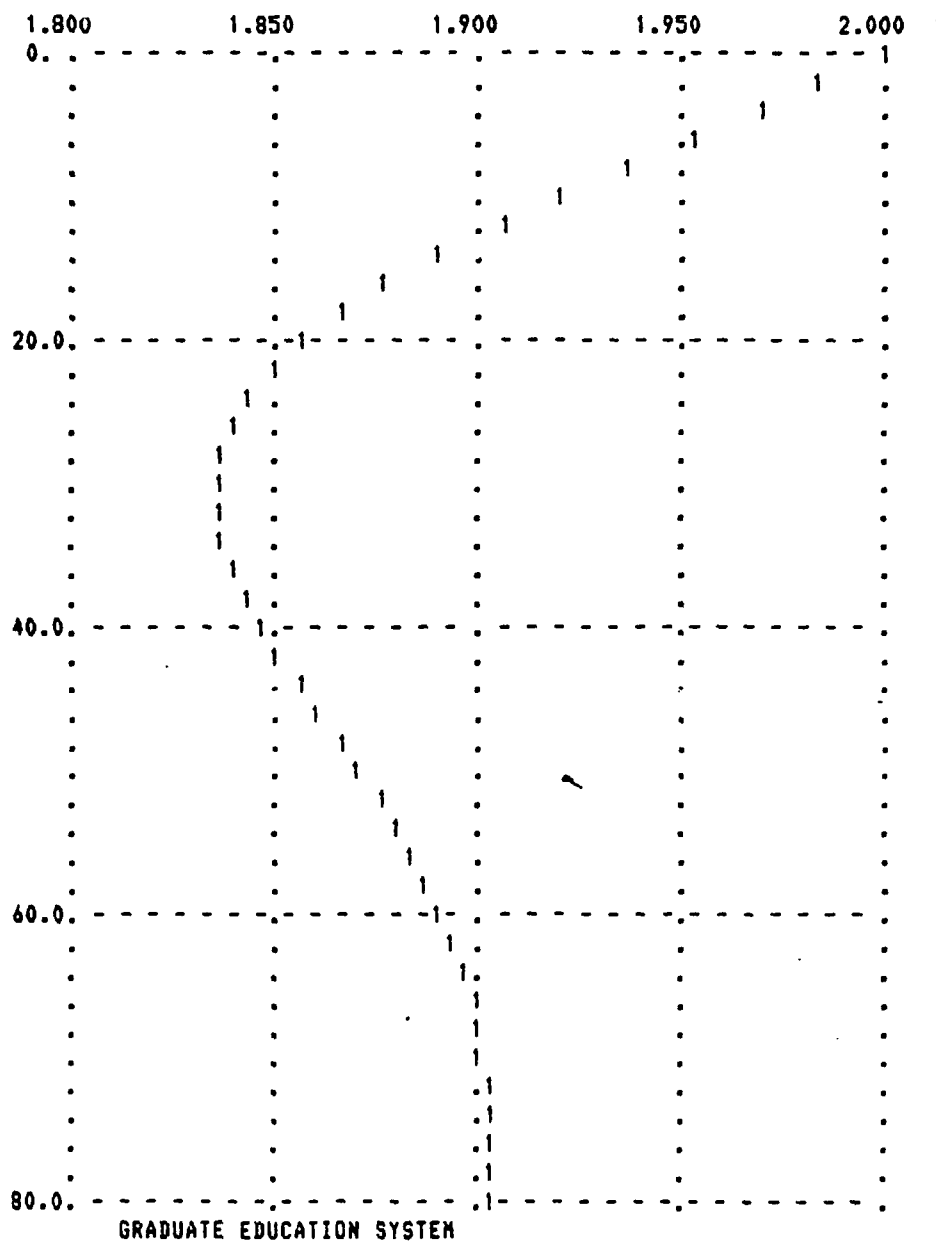


Figure D-13. Aggregate Coverage Ratio (RUN 13).

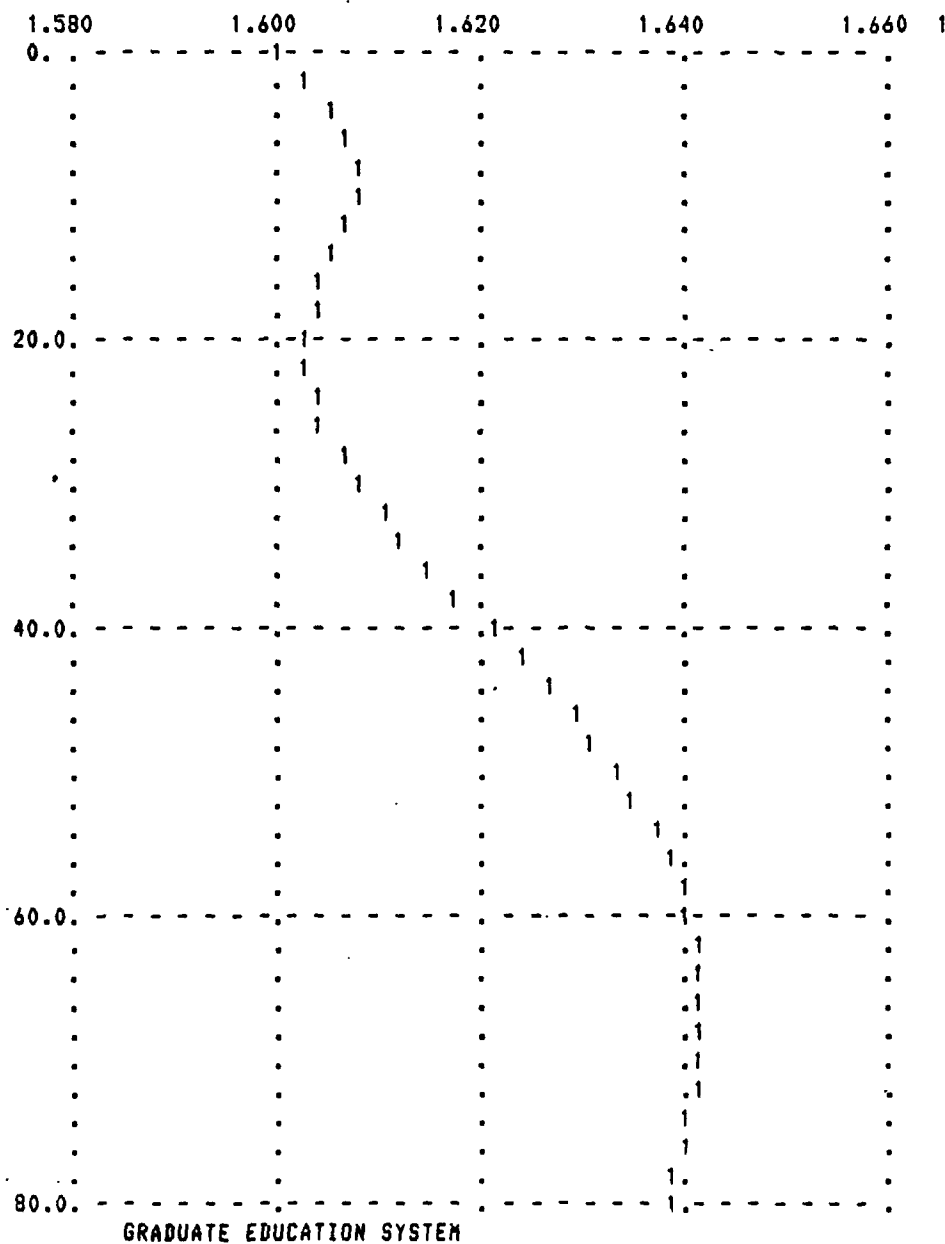


Figure D-14. Aggregate Coverage Ratio (RUN 14).

0.800	1.300	1.800	2.300	2.800	12345
0.	.	2	.	.	2345
.	.	23	5	.	34
.	.	32	5	.	24
.	.	34	2	5	.
.	.	3	4	2	5
.	.	3	4	2	5
.	.	3	4	2	5
.	.	3	4	2	5
.	.	3	4	2	5
.	.	3	4	2	5
20.0	.	34	.	2	5
.	.	34	.	2	5
.	.	34	.	2	5
.	.	34	.	2	5
.	.	34	.	2	5
.	.	34	.	25	.
.	.	43	.	25	.
.	.	43	.	2	25
.	.	43	.	52	.
40.0	.	43	.	52	.
.	.	43	.	52	.
.	.	43	.	5	2
.	.	43	.	5	2
.	.	43	.	5	2
.	.	4	3	5	2
.	.	4	3	5	2
.	.	4	3	5	2
.	.	4	3	5	2
.	.	4	3	5	2
60.0	.	4	3	52	.
.	.	4	3	52	.
.	.	4	3	52	.
.	.	4	3	52	.
.	.	43	.	52	.
.	.	43	.	2	25
.	.	43	.	2	25
.	.	43	.	2	25
.	.	43	.	2	25
.	.	43	.	2	25
80.0	.	43	.	2	25
.	.	43	.	2	25

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Figure D-14A. Coverage Ratio by Grade (RUN 14).

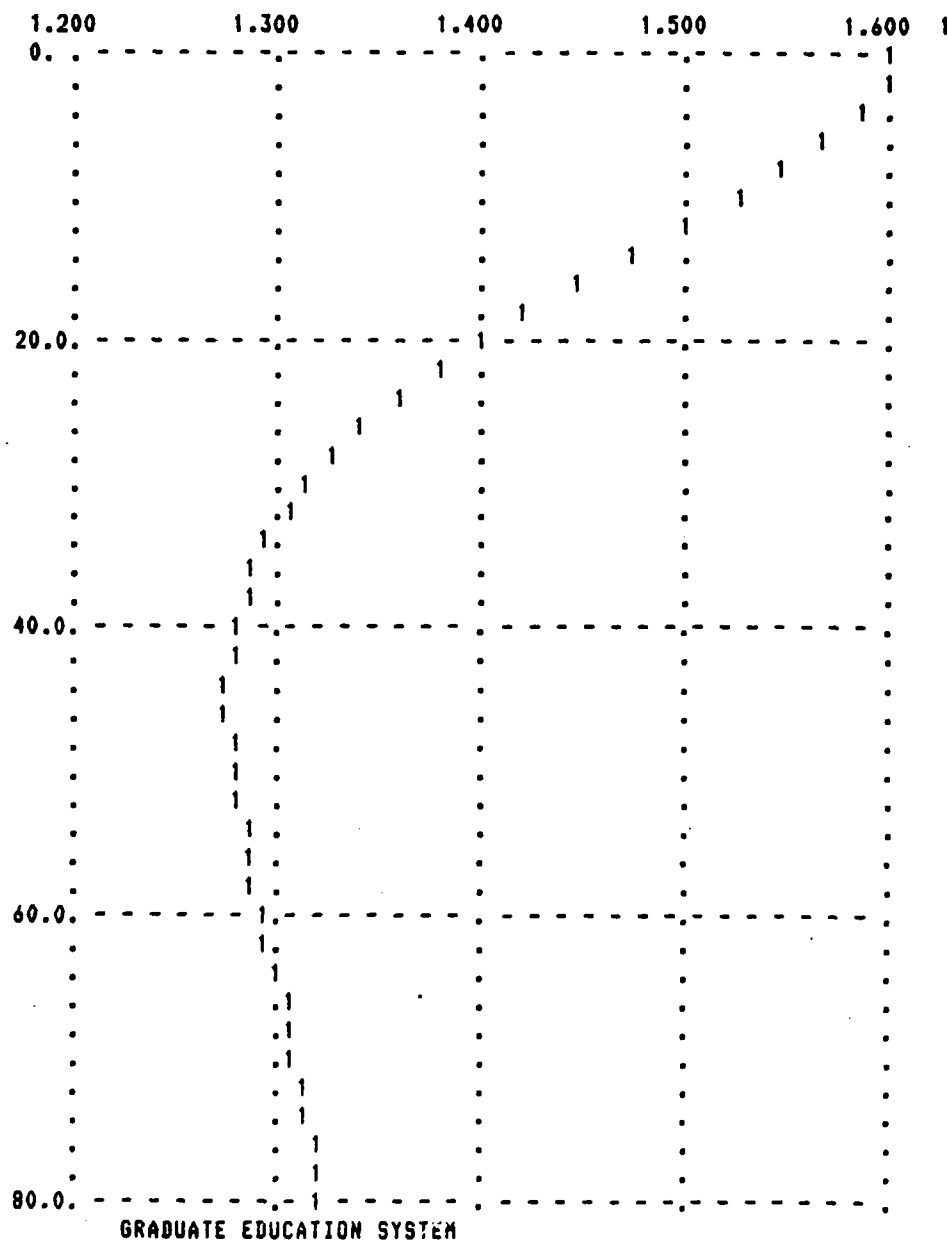


Figure D-15. Aggregate Coverage Ratio (RUN 15).

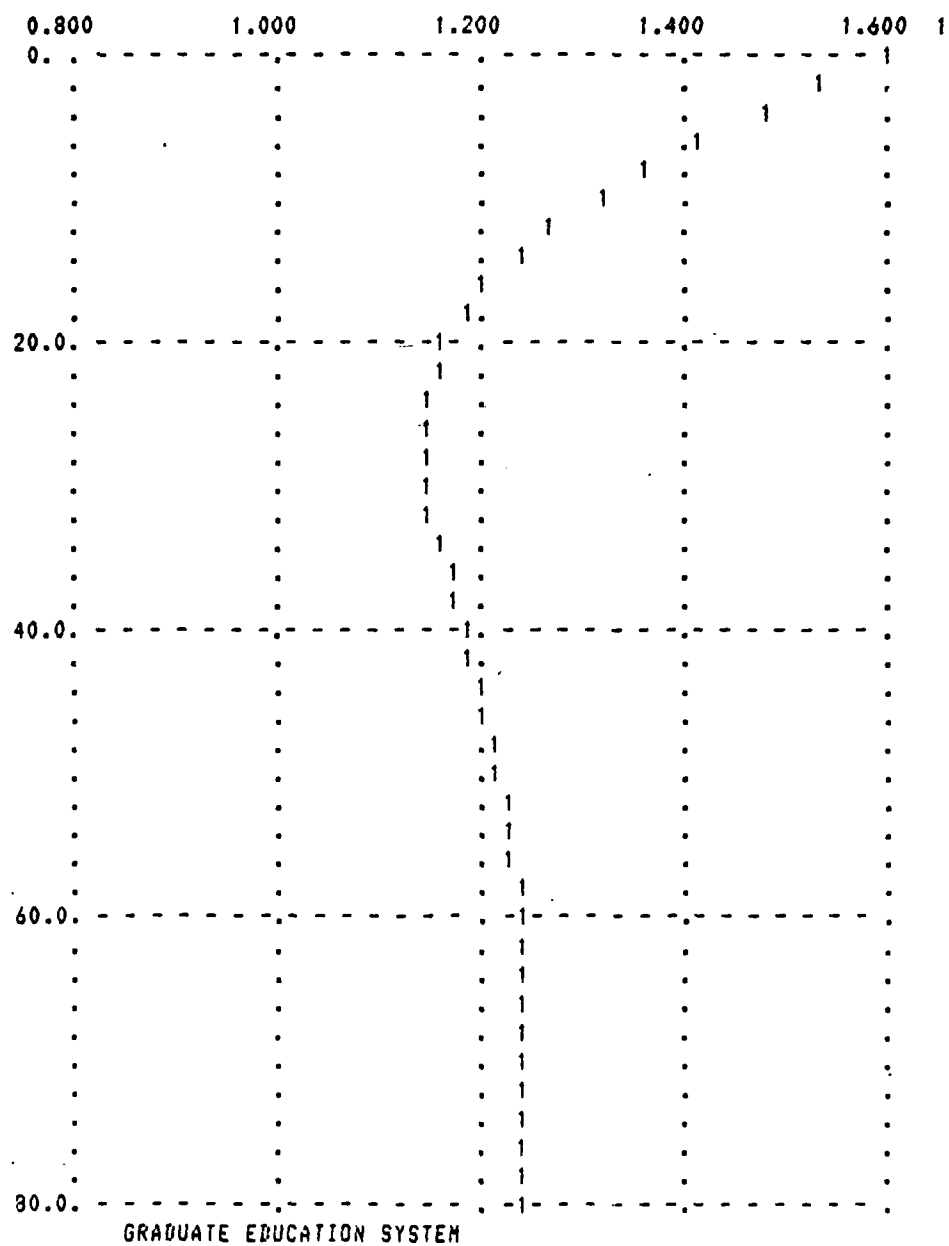
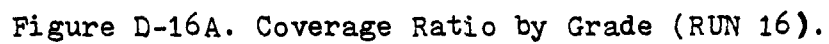


Figure D-16. Aggregate Coverage Ratio (RUN 16).



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